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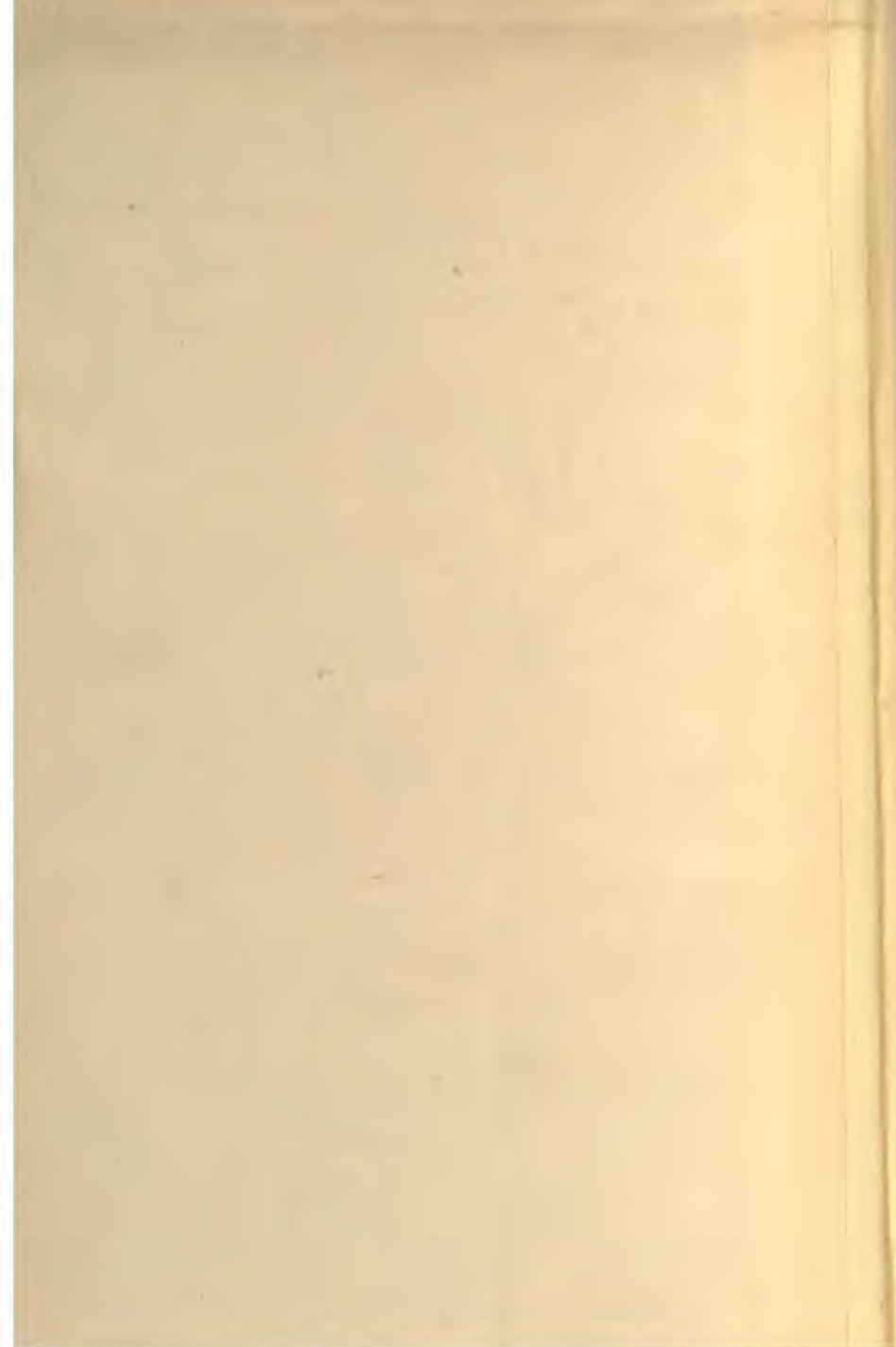
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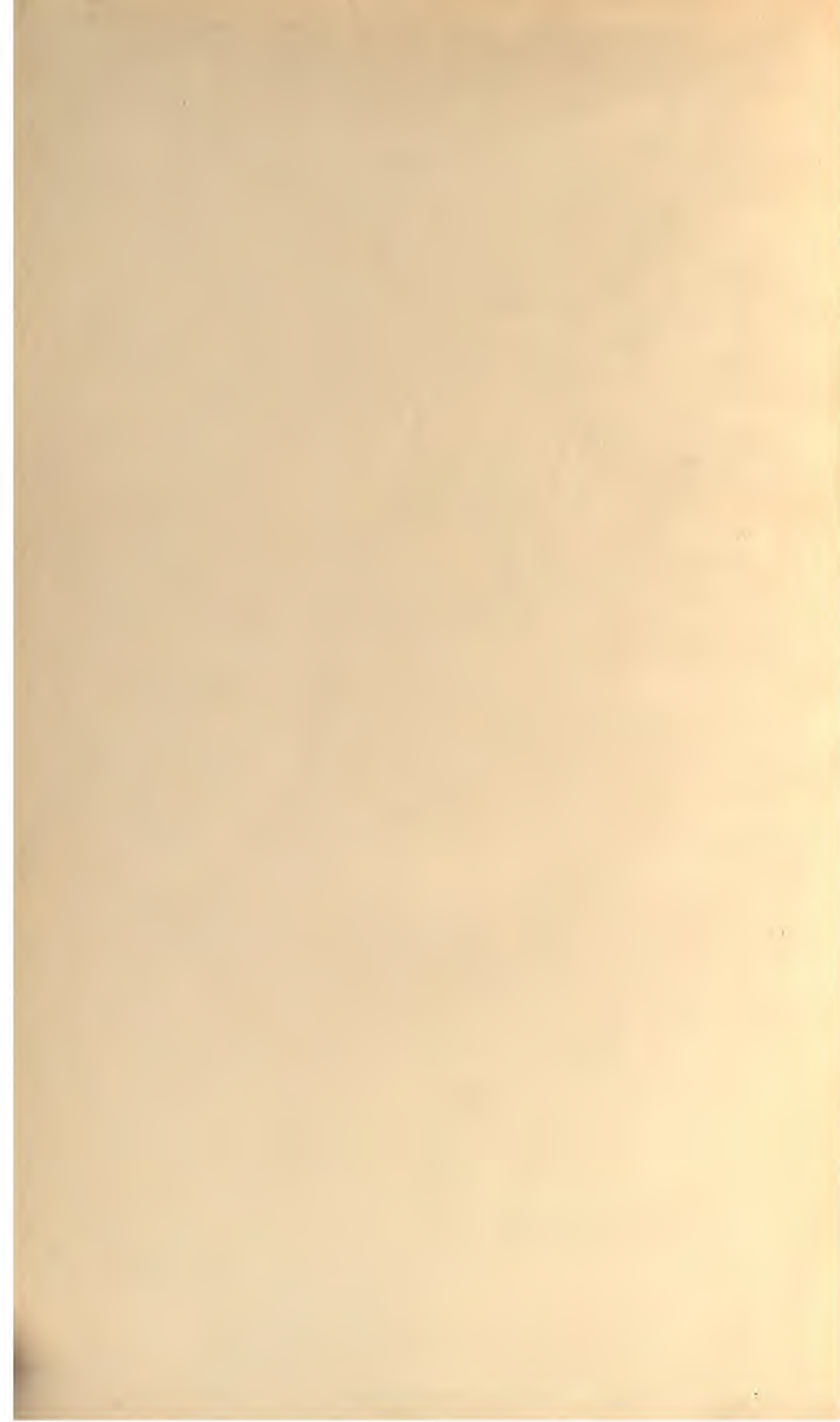
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W. T. SNYDER, PRESIDENT 1916

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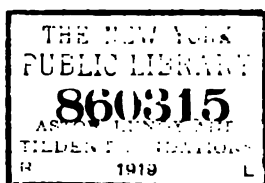
of

**★ ASSOCIATION OF IRON & STEEL
ELECTRICAL ENGINEERS**



1916

**TENTH ANNUAL CONVENTION
HOTEL LA SALLE, CHICAGO, ILL.
SEPTEMBER 18-22, 1916**



860315

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C. A. MENK, 2nd. Vice Pres.—Carnegie Steel Co., Munhall, Pa.
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E. FRIEDLAENDER, Past Pres.—Carnegie Steel Co., Braddock, Pa.

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E. FRIEDLAENDER.

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M. B. SPAULDING.

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G. W. RICHARDSON.

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C. PIRTLE.
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FRANK SMITH.
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D. B. RUSHMORE.
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ADAM SLATER.
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SAMUEL SUEKOFF.
R. TSCHENTSCHER.
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PAST-PRESIDENTS, 1908 to 1915

JAMES FARRINGTON—1908.
JOHN C. REED—1909.
F. P. TOWNSEND—1910.
L. R. PALMER—1911.
B. R. SHOVER—1912.
C. W. PARKHURST—1913
E. FRIEDLAENDER—1914.
O. R. JONES—1915.

OFFICERS AND COMMITTEES FOR 1917

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F. D. EGAN, Pres.—Pittsburgh Crucible Steel Co., Midland, Pa.
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JAS. FARRINGTON, Treasurer—La Belle Iron Works, Steubenville, O.
W. T. SNYDER, Past President—National Tube Co., McKeesport, Pa.
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C. A. MENK.

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FRED H. WOODHULL.

MINUTES OF TENTH ANNUAL CONVENTION

HELD AT HOTEL LA SALLE, CHICAGO, ILL.
SEPTEMBER 18-22, 1916

The meeting was called to order by the president, W. T. Snyder, at 10:30 A. M., Monday, September 18th, 1916.

Committee reports for the year of 1916 follow:

REPORT OF MEMBERSHIP COMMITTEE

	Hon.	Act.	Assoc.	Total
Admitted	0	38	75	113
Resigned	0	2	7	9
Dropped, non-payment of dues	0	1	2	3
Deceased	0	0	3	3
Reinstated	0	0	1	1
Changed to Associate	0	3	0	3
Changed to Active	0	0	1	1
Total Membership, Jan. 1, 1916	6	110	239	355
Total Membership, Dec. 31, 1916	6	143	305	454
Gain for year, members	0	33	66	99
Gain for year, per cent	0	30%	27.6%	28%

The report shows 38 Active and 75 Associate members were admitted during the year. One Associate member who resigned was reinstated, making a gain of 38 Active and 76 Associates, a total gain of 114 members.

The loss in members was 3 Active and 12 Associate, a total of 15; leaving a net gain for the year of 33 Active and 66 Associate, a total of 99.

While the membership increase for the year is in exact ratio of two Associates to one Active member, the percentage increase in the total membership is 30% for Active, 27.6% for Associate, and 28% for the entire membership.

Respectfully submitted,
W. O. Oschmann,
Chairman.

SECRETARY'S REPORT

Following is a list of meetings held in Pittsburgh, Cleveland and Philadelphia in 1916 to date.

Pittsburgh Meetings.

January 15th, 1916, Seventh Avenue Hotel. At this meeting two addresses were given; one by the president, W. T. Snyder, entitled "Objects and Scope of the A.I. & S.E.E." and one by Mr. Paul Lincoln of the Westinghouse Electric & Mfg. Co., entitled "Reminiscences of Niagara." This meeting had a total attendance of 62.

February 19, 1916, Seventh Avenue Hotel. At this meeting an address was given by Mr. L. R. Palmer, Chief Inspector, Dept. of Labor and Industry, State of Pennsylvania, on "The Pennsylvania Department of Labor and Industry, the National Safety Council and Accident Prevention", and an address by our President, W. T. Snyder, on "Review of Safety Work of the A.I. & S.E.E." Attendance, 86.

March 18, 1916, Seventh Avenue Hotel. Under the auspices of the Central Station Power Committee, Clark S. Iankton, chairman. The meeting was devoted to "Important Points in Consideration of Central Station Power for Steel Mills," and Joseph McKinley, of the Duquesne Light Co., opened the meeting by reading a paper entitled, "The Use of Central Station Power Service in Steel Mills", after which other contributions and discussions followed. Attendance 110.

April 15, 1916, Fort Pitt Hotel. Under the auspices of the Electrical Development Committee, S. C. Coey, chairman. The meeting was devoted to "Latest Development in New Apparatus and Appliances," and discussion. Attendance, 76.

May 20, 1916, Fort Pitt Hotel. Under auspices of the Standardization Committee, F. D. Egan, chairman. The meeting was devoted to a discussion on standardization rules. Attendance, 72.

June 17, 1916, Ft. Pitt Hotel. Under the auspices of the Educational Committee, Charles A. Menk, chairman.

Educational work of the General Electric Co., Westinghouse Electric & Mfg. Co., Homestead Steel Co., Carnegie Technical Schools and the University of Pittsburgh was explained. Attendance, 95.

Directors' Meetings only were held in July and August.

October 21st, 1916, Ft. Pitt Hotel. This meeting was a joint session with the Pittsburgh Section of the A. I. E. E. The meeting was devoted to the reading and further discussion of the paper entitled "Central Station Power for Steel Mills," which was read at the Chicago Convention. Attendance 83.

November 18th, 1916, Ft. Pitt Hotel. Mr. David Wright, Power & Mining Dept., General Electric Co., presented a paper entitled "Variable Speed A-C Motors for Mill Drive." Attendance 78.

December 16th, 1916, Ft. Pitt Hotel. The meeting was devoted to the presentation of a "Specification," by F. D. Egan, for Steel Mill Cranes. Attendance 75.

Cleveland Meeting

Cleveland, May 6, 1916, Hotel Statler. The meeting was devoted to a discussion on Central Station Power for Steel Mills and Industrial Plants. Attendance, 85.

Philadelphia Meetings

May 6, 1916, Hotel Adolphus. James A. Shepard, of the Shepard Electric Crane and Hoist Co., read a paper entitled "The Electric Crane in the Steel Mills." Attendance, 38.

June 8, 1916, Colonnade Hotel. M. I. Nusim, Southworks Foundry & Machine Co., presented a paper on "Steam Turbines, Bleeder, Low Pressure and Mixed Flow", an informal talk by W. T. Snyder on Association affairs was also given. Attendance 63.

October 7th, 1916, Continental Hotel. This meeting was devoted to the reading and further discussion of the paper on "The Electric Furnace," by Mr. G. W. Richardson, which was read at the Chicago Convention, and the presentation of a paper on "Electric Steel Making," by Robert M. Wynn.

November 4th, Marston Hotel. Mr. H. F. Stratton,

read a paper entitled "The Operation of Mechanically-Connected Direct-Current Motors Permanently in Series or Permanently in Parallel."

December 2nd, 1916, Majestic Hotel. Mr. D. M. Petty presented a paper on "A-C Phase-Wound Motors versus Adjustable Speed D-C. Motors."

In addition to the copies sent out by the Editing Committee there were 153 copies of the 1915 Proceedings and 7 copies of the 1914 Proceedings sent out from the Secretary's office.

With the present prosperity there is no excuse for neglecting payment of dues and members are requested to liquidate their indebtedness to the Association at once.

Respectfully submitted,

W. O. Oschmann,
Secretary.

REPORT OF EDITING COMMITTEE

Following is a report of the Editing Committee for year 1916, to date:

The following papers have been contributed for the 1916-Convention, and advance copies mailed on August 11, 1916:

"The Value of Records to an Operating Engineer," by Ray S. Huey.

"Cost versus Upkeep of Direct-Current Motors," by A. M. MacCutcheon.

"Central Station Power for Steel Mills," by A.I. & S.E.E. Central Station Power Committee.

"Design of Structures for Steel Mills," by Chas. A. Randorf.

"Underground Distribution Systems," by George J. Newton.

"The Unaflo Engine," by W. Trinks.

"Steel Conductors for Transmission Lines," by H. B. Dwight.

"The Advantages of Modern Types of Direct-Current Machines," by David Hall.

"Mechanical and Electrical Operation of the Heroult Electric Arc Furnace," by George W. Richardson.

"Operating Characteristics of an Electric Reversing Blooming Mill," by E. S. Jefferies.

"Control of D-C and A-C Motors as applied to Cranes," by Paul Caldwell.

"Portable Electric Tools as applied to the Iron and Steel Industry," by A. M. Andresen.

The following papers, read and discussed at the Pittsburgh Monthly Meetings, were printed in pamphlet form and distributed among members:

"Objects and Scope of the A.I. & S.E.E.," by W. T. Snyder.

"Reminiscences of Niagara," by Paul M. Lincoln.

"By-Laws (Amended)."

"Review of Safety Work of the A.I. & S.E.E.," by W. T. Snyder.

"Important Points in Consideration of Central Station Power for Steel Mills," by A.I. & S.E.E. Central Station Power Committee.

"Latest Developments in New Apparatus and Appliances," by A.I. & S.E.E. Electrical Development Committee.

"Standardization," by A.I. & S.E.E. Standardization Committee.

"Apprenticeship," by A.I. & S.E.E. Educational Committee.

New Membership Lists, corrected to July 1, 1916, were printed and distributed with the 1916-Advance Papers.

Suggested Amendments to the Constitution were drawn up, printed and distributed to the Active Membership in conjunction with the ballots for election of 1917-Officers, the Active Members being requested to vote for or against the adoption of the suggested Amendments on their ballots; the result of the vote to be announced at the 1916-Convention.

Five Hundred (500) Copies of the 1915-Proceedings were printed and 297 copies were distributed by this Committee.

Respectfully submitted,
E. Friedlaender,
Chairman.

REPORT OF SAFETY COMMITTEE

During the current year, the unusual business conditions and press of work in our different operations has made it impossible to hold formal meetings of the Safety Committee. There has been considerable correspondence between the members of the Committee, relative to safer conditions in steel mills, and especially with reference to the use of electric current.

The Committee had a careful search of the literature made to learn whether it were possible to draw a conclusion as to what might be considered as safe current and what dangerous. The report discloses that there have been a few deaths reported as resulting from 95 to 110 volts, and several cases of death have been reported as occurring from 220 to 250 volts, and, of course, deaths from higher voltages; but no definite conclusion could be drawn because of a lack of detail in the literature.

The Committee also made an investigation of safety belts for linemen, and does not think it wise at this time to decide on any one set of specifications as standard, because linemen's belts and belt fittings are now undergoing experiments and tests. Because of the frequent failure of linemen's belts and the lack of standardization in this respect, the Committee would suggest that this subject be further investigated by the incoming Safety Committee.

Your Committee would also suggest that further consideration be given by the new Safety Committee to the practicability of using a current not to exceed 250 volts A-C. for operating mill motors installed in work rooms where hurried repairs are made and where inexperienced workmen are in constant danger of accidental contact.

Respectfully submitted,
R. J. Young
Chairman.

REPORT OF EDUCATIONAL COMMITTEE

As Chairman of your Educational Committee, which was appointed at the 1915 Convention held in Detroit, I beg to report that the Committee met on several occasions, but as the majority of the members have not attended any of these meetings, it was impossible to do any business of a substantial nature. I wish to report that the June meeting held in Pittsburgh at the Fort Pitt Hotel was under the direction of the Educational Committee. This meeting had an attendance of 95. The speaker of the evening was Mr. M. W. Alexander of the General Electric Company, West Lynn, Mass., who outlined the educational work as being accomplished by that company, which was complete in every way and very much enjoyed by the members present. Mr. C. R. Dooley of the Westinghouse Electric & Mfg. Company was also present and gave a brief outline of the educational work as being carried on by that company. We also had present, Prof. John W. Hallock of the University of Pittsburgh, Prof. D. C. Dennison of the Carnegie Institute of Technology, and Mr. A. F. Wolf of the Homestead Steel Works of the Carnegie Steel Co., who all gave short talks on the educational work as being carried on by the different institutions which they represent.

Respectfully submitted,

Chas. A. Menk,
Chairman.

REPORT OF CENTRAL STATION POWER COMMITTEE

The Central Station Power Committee had its inception at our last annual meeting when our past-president, E. Friedlaender, made the suggestion that such a committee would be of service to the Association.

The committee as appointed by President Snyder has faithfully endeavored to perform its duties and now presents the report of its activities:

Number of committee meetings held during the year, four—Papers prepared, two.

On March 18th, the committee had charge of the monthly meeting of the Pittsburgh Section. Mr. Joseph McKinley

ably presented a paper on "The Use of Central Station Power Service in Steel Mills."

His paper was freely discussed by both association members and representatives of Central stations.

The Committee recommends that its existence be continued under a new personnel, that its scope be broadened to include the generation of power, also the power requirements of the steel plant. It also recommends that its name be changed to "The Power Committee" instead of the Central Station Power Committee.

The Committee further suggests to the new committee, if appointed, that a technical data bureau be established whose duty would be to collect and tabulate useful technical data for the use of the Association.

Respectfully submitted,
Clark S. Lankton,
Chairman.

REPORT OF ELECTRICAL DEVELOPMENT COMMITTEE

In presenting a number of short talks on the progress being made in various lines of electrical work, as was done in the April Meeting of the Pittsburgh Section of the A. of I. & S.E.E., I feel that the Electrical Development Committee has established a precedent that is worthy of continuing in the future. Points covered in this meeting included some of the recent developments in gas engines, switchboards, transformers, coal and ore handling machinery, shear operation, and plant illumination. To those members who were not present at this meeting I would recommend that they go over the reports of this meeting. As one of the principal advantages that the members of this Association have is in getting information on the details of construction and operation of new types of apparatus, work of this kind is of very considerable value. As some of the subjects were too large to be taken up at this April meeting they are to be presented in the form of papers at the Chicago Convention.

Respectfully submitted,
Stewart C. Coey,
Chairman.

REPORT OF STANDARDIZATION COMMITTEE

During the current year, several meetings were called. At one meeting there was an active member present. At the other meetings various associate members were present.

The meeting, held May 20, 1916, was under the auspices of the above committee. At this meeting, the active members, who were to participate, were again absent. The views of the Manufacturers were ably presented. A number of the operating members of the association who attended this meeting gave impromptu talks that were gratifying to the chairman and to the members that attended.

The Standardization Committee promised to present a paper at the 1916 Convention. From the experience gained during the year, the chairman felt that, due to the stress of present business, the active members would not be able to assist and for this reason, the paper was dropped.

Respectfully submitted,

F. D. Egan,
Chairman.

PRESIDENT'S ADDRESS

By W. T. SNYDER

At the January meeting in Pittsburgh, we outlined certain changes and recommendations that we believed were necessary if the Association was to continue to progress with the rapid growth of the industry and the more rapid growth of the use of electricity in the industry. We referred to the fact that there was more interest in the Association among members in the Pittsburgh District than any other section of the country, which we attributed largely to the influence of the Pittsburgh monthly meetings, and which seemed to indicate the need of local sections in the principal geographic centers of the steel industry beginning with Cleveland, Philadelphia, and Chicago, and that starting these local sections would undoubtedly result in an increase in membership because the Association would be more useful to members in territory where these sections are active and

thereby afford a greater incentive for those eligible to enroll.

With four local sections actively at work, the logical step would be the publication of transactions at more frequent intervals than once a year, perhaps six issues per year of the transactions of local sections and a yearly issue of Proceedings of our Annual Convention.

The increase in membership and the more frequent publication of the transactions would, we pointed out, result in a decided increase in the work of the executive officers, which has already reached the point where it is burdensome to those on whom it falls to be done gratuitously and very often at the expense of neglecting their regular duties. It is imperative therefore that you now engage a permanent Secretary at a salary sufficient to attract a capable man.

We pointed out also that even without a paid Secretary the legitimate income of the Association would not meet the expenses of the Association, and we recommended the consideration of a new grade of membership or letting down the bars to a limited degree so as to increase the active membership or to increase the dues of the associate membership.

Our plan of action during the year has been directed toward putting into effect the recommendations then made and we will outline what has been accomplished.

We are pleased to report that local sections have been started in Philadelphia and Cleveland as you no doubt know, which give promise of being just as active as the local section in Pittsburgh, and while we were not successful in getting action in Chicago, we expect to have a local section going in Chicago before the end of this year.

After careful consideration and after gathering the sentiment of the associate membership the Board of Directors recommended that dues of associate membership be increased to \$7.50 per year because the income from dues averages \$6.50 per member and the expenses are \$9.00 per member, of which the active member pays \$10.00 and the associate member pays \$5.00. With the increase in dues of associate members, the income from dues will average \$8.50 per member, which with entrance fees, will then equal the expenses, not including the expenses of a paid Secretary.

To meet this expense, at least until the membership increases sufficiently to do otherwise, the Board of Directors,

after taking the matter up with some of the larger firms in the iron and steel industry recommended that we admit to firm membership the different companies in the iron and steel industry according to the following schedule:

Firms employing less than 2001 employees, \$25.00 per yr.

Firms employing more than 2000 employees and less than 5001, \$50.00 per yr.

Firms employing more than 5000 employees, \$100 per yr.

You were asked to vote on these amendments to the Constitution at the time that you voted for officers for next year. You were also asked to vote on other amendments to the Constitution which, however, are of minor importance to those increasing the dues of associate members and admission of firms to membership, insofar as they effect the welfare of the Association.

The By-Laws of the Association were revised and amended at the February Meeting of the Board of Directors and copies distributed to the membership as a part of the report of the February Meeting of the Pittsburgh Section. The principal revisions and amendments were more definite rules relative to the collection of dues, authorization and payment of bills, bonding of Secretary and Treasurer, and providing rules for the establishment and organization of branch sections.

During the year there were held in Pittsburgh six regular monthly meetings, five of which were under the auspices of the five special committees, the Chairman of the committee acting as Chairman of the meeting. As the particular work allotted each of these committees covers nearly the entire range of activities of our Association—Education, Standardization, Safety, Central Station Power, and New Developments—it would seem that they should be continued.

The plan of setting aside a regular monthly meeting of the various sections for consideration and discussion of the work of the different committees would tend toward extremely valuable committee reports at each annual meeting and result in interesting and valuable record. The function of all committees, particularly special committees is or should be to gather data and information from individuals and disseminate their findings and conclusions to the general membership.

We submit to your consideration that the Association is primarily for the benefit of the iron and steel industry as represented by the active membership and that the industry, as well as the membership in general, including the associate members, would benefit by the more active participation of the active members in reading and discussing the papers.

MEMBERS AND GUESTS REGISTERED AT THE TENTH
ANNUAL CONVENTION

Active Members

B. G. Beck
C. E. Bedell
S. J. Blake
R. C. Boak
V. I. Brinker
James Caputo
K. H. Cederlund
Jas. F. Chapman
A. B. Churchill
M. W. Cobbledick
S. C. Coey
H. B. Conover
John E. Cooper
Harry A. Cox
H. H. Craiglow
John B. Davis
John S. Delaney
W. F. Detwiler
F. D. Egan
Jas. Farrington

Gordon Fox
L. F. Galbreath
B. W. Gilson
G. W. Haney
C. W. Harper
Comer D. Hazen
Ray S. Huey
Wm. Jackson
E. S. Jefferies
O. R. Jones
Chas. A. Kafer
John F. Kelly
F. H. Kittredge
C. S. Lankton
G. H. McFeaters
R. L. McIntosh
C. A. Menk
Chas. E. Miller
Jas. L. Mills
J. A. Morgan

Wm. Nimz
W. O. Oschmann
L. R. Palmer
D. M. Petty
A. G. Place
John E. Powers
L. R. Rankin
John C. Reed
G. W. Richardson
M. S. Robinson
R. R. Shepherd
R. S. Shoemaker
B. R. Shover
W. T. Snyder
R. Tschentscher
A. M. Tucker
T. E. Tynes
Frank A. Wiley
J. H. Wilson
F. H. Woodhull

Associate Members

A. M. Andresen
A. A. Anderson
A. L. Arenberg
R. L. Baker
C. A. Beck
Wesley J. Beck
T. E. Beddoe
O. M. Bercaw
C. N. Bergmann
H. L. Bradley
G. R. Brandon
Jos. Breslove
F. J. Brittingham
F. J. Burd
Paul Caldwell
Arthur Cameron

W. D. Cameron
R. H. Carter
C. B. Coates
J. O. Corbett
Lester H. Couchey
F. B. Crosby
H. E. Darby
D. G. Darling
C. S. Dauler
W. L. DeCoursey
W. T. Dean
Jas. R. Downs
Paul A. Dratz
J. N. Elliott
A. L. Eustice
F. R. Fishback

T. J. Fleischer
A. D. Fonger
Frank D. Frawley
Robt. F. Freeman
Chas. D. Gilpin
W. Greenwood
J. G. Harvey
Stanton S. Heatz
C. T. Henderson
Ludwig Hommel
A. F. Hovey
C. A. Huebner
J. E. N. Hume
P. W. Jones
B. J. Kacin
Ray Kauffman

Ralph H. Kilner
B. G. Kodjbanoff
Saul Lavine
W. P. Leighton
E. F. J. Lindberg
C. C. Lynde
John H. Lytle
Jos. McKinley
J. J. McQuillen
W. C. Minier
R. H. Moore
Thos. J. Muir
Edwin J. Murphy
R. M. Pateracki
Karl A. Pauly
Clairborne Pirtle

W. P. Poynton
W. H. Purcell
R. L. Rathbone
Harry D. Rei
H. S. Richardson
C. S. Ripley
Julian Roe
Alex. R. Ross
David B. Rushmore
S. Russell, Jr.
R. H. Ruth
H. H. Ryde
Henry J. Sage
Otto Schaumberg
F. H. Semple
Wm. W. Soffe

Paul H. Stambaugh
W. D. Steele
G. E. Stoltz
Wm. F. Sullivan
Alfred H. Swartz
A. J. Thompson
F. P. Townsend
A. E. Tregenza
E. P. Van Kirk
H. E. Watson
Dwight G. Welling
R. G. Widdows
Brent Wiley
W. H. Williams
F. C. Young
Eric Zachau

Guests

Chas. H. Alber, Chicago, Ill.
A. C. Andresen, Chicago, Ill.
Mrs. A. M. Andresen, Pgh., Pa.
Edward Alpin, Chicago, Ill.
K. A. Auty, Chicago, Ill.
Mrs. R. L. Baker, Chicago, Ill.
F. T. Bangs, Chicago, Ill.
H. L. Barnholdt, Pittsburgh, Pa.
A. B. Besch, Pittsburgh, Pa.
E. L. Behrens, Muskegon, Mich.
W. L. Bell, St. Louis, Mo.
J. J. Belrois, Joliet, Ill.
L. R. Berkeley, Cleveland, O.
Theo. Blech, Waukegan, Ill.
C. S. Boggs, Chicago, Ill.
Lawrence C. Bowes, Chicago, Ill.
Henry N. Brooks, Chicago, Ill.
A. N. Brown, Chicago, Ill.
A. W. Browne, Waukegan, Ill.
H. L. Caldwell, Chicago, Ill.
Mrs. W. D. Cameron, Chicago, Ill.
A. G. Carlson, Chicago, Ill.
W. P. Chandler, Jr., Clanton, Pa.
J. P. Cline, Chicago, Ill.
Mrs. E. C. Coey, Youngstown, O.
Mrs. J. O. Corbett, Carnegie, Pa.
O. L. Crippen, Youngstown, O.
Edwin L. Crosby, Detroit, Mich.
T. E. Crossman, New York City.
W. J. Crompton, Chicago, Ill.
R. W. Davis, Milwaukee, Wis.
Howard Doudle, Cleveland, O.
A. J. Duffey, Chicago, Ill.
Mrs. A. J. Duffey, Chicago, Ill.
H. B. Dought, Hamilton, Canada.
Mrs. Dwight, Hamilton, Canada.
A. C. Dyer, Pittsburgh, Pa.
Mrs. F. D. Egan, Midland, Pa.
W. H. Elliott, Chicago, Ill.

W. H. Elliott, Jr., Chicago, Ill.
Ben. D. Ernestine, Chicago, Ill.
Mrs. A. L. Eustice, Chicago, Ill.
Horace H. Field, Chicago, Ill.
Geo. P. Flick, Tarentum, Pa.
Mrs. A. D. Fonger, Chicago, Ill.
A. H. Foote, Chicago, Ill.
M. M. Fowler, Chicago, Ill.
Charles J. French, Chicago, Ill.
Mrs. B. W. Gilson, Youngstown, O.
H. V. Green, Chicago, Ill.
W. S. Hall, South Chicago, Ill.
David Hall, East Pittsburgh, Pa.
H. J. Harries, Milwaukee, Wis.
N. K. Hartford, Cleveland, O.
E. L. Hegeman, Chicago, Ill.
A. Herz, Chicago, Ill.
J. J. Hess, Joliet, Ill.
A. T. Hinckley, Niagara Falls, N. Y.
J. J. Holmann, Chicago, Ill.
A. R. Holcomb, Cannonsburg, Pa.
H. Hooper, Chicago, Ill.
H. D. James, Pittsburgh, Pa.
Mrs. O. R. Jones, Youngstown, O.
Miss Alberta Jones, Youngstown, O.
P. Jumpersfeld, Chicago, Ill.
Mrs. Ralph H. Kilner, Chicago, Ill.
Mrs. F. H. Kilredge, Joliet, Ill.
W. Koon, South Chicago, Ill.
A. H. Koon, Chicago, Ill.
K. Landis, Chicago, Ill.
Mrs. Clark S. Lankton, Pgh., Pa.
John G. Learned, Chicago, Ill.
H. F. Lehnsohl, Chicago, Ill.
A. E. Liebock, Chicago, Ill.
Mrs. Luce, Chicago, Ill.
Geo. H. Lumsberg, Chicago, Ill.
D. A. Lyon, Salt Lake City, Utah.
A. M. MacCabe, Cleveland, O.

Mrs. A. S. Merrill, Chicago, Ill.	Mrs. F. H. Semple, Chicago, Ill.
Mrs. R. L. McIntosh, Indiana Harbor, Ind.	Geo. Shelton, Granite City, Ill.
Mrs. McKinley, Pittsburgh, Pa.	J. W. Sheffer, Braddock, Pa.
R. H. McLain, Schenectady, N. Y.	Lee Skipwirth, Chicago, Ill.
James Maloney, Carnegie, Pa.	W. H. Slingluff, Chicago, Ill.
J. C. Marshall, Chicago, Ill.	E. S. Small, Chicago, Ill.
E. H. Martindale, Cleveland, O.	F. C. Smith, Chicago, Ill.
Miss Miller, Youngstown, O.	Mrs. W. T. Snyder, McKeesport, Pa.
Mrs. Jas. L. Mills, Chicago, Ill.	L. C. Spare, Chicago, Ill.
R. C. Mons, Chicago, Ill.	Geo. T. Street, Youngstown, O.
A. G. Montgomery, Pittsburgh, Pa.	R. S. Sturgis, Chicago, Ill.
Mrs. R. H. Moore, Chicago, Ill.	Mrs. A. H. Swartz, Cleveland, O.
Mrs. William Nimz, Cleveland, O.	Miss Elfie Swartz, Cleveland, O.
Elbert F. Norton, Chicago, Ill.	Miss Mae Swartz, Cleveland, O.
E. K. Norton, Canonsburg, Pa.	B. W. Sweet, Cleveland, O.
Mrs. O'Harah, Chicago, Ill.	Mrs. A. J. Thompson, Cleveland, O.
Mrs. Wm. Oschmann, Pgh., Pa.	R. P. Tillotson, Chicago, Ill.
Walter Painter, Chicago, Ill.	Mrs. A. E. Tregenza, Chicago.
W. H. Patterson, East Pgh. Pa.	W. Trinks, Pittsburgh, Pa.
E. J. Pirtzcker, Chicago, Ill.	Mrs. R. Tschentscher, Chicago, Ill.
Mrs. C. Pirtle, Cleveland, O.	John T. Valenta, Chicago, Ill.
Mrs. John E. Powers, Sharon, Pa.	E. H. Waring, Ampere, N. J.
Mrs. W. P. Poynton, Pittsburgh, Pa.	Mrs. W. E. Watters, Chicago, Ill.
Mrs. Pratt, Chicago, Ill.	S. B. Wiggins, Detroit, Mich.
C. A. Randorf, Buffalo, N. Y.	Mrs. F. A. Wiley, Chicago, Ill.
Mrs. L. R. Rankin, Sharon, Pa.	Mrs. Brent Wiley, Pittsburgh, Pa.
Mrs. H. S. Richardson, Cleveland, O.	R. L. Wilkinson, Chicago, Ill.
A. T. Riggs, Chicago, Ill.	T. H. Williams, Chicago, Ill.
Mrs. M. S. Robinson, Donora, Pa.	Mrs. W. H. Williams, Chicago, Ill.
W. R. Runner, Wilkinsburg, Pa.	E. C. Wilson, Chicago, Ill.
Mrs. R. H. Ruth, Pittsburgh, Pa.	Mrs. J. H. Wilson, Middletown, O.
	S. Wolff, Chicago, Ill.

Summary

Active Members...	60
Associate Members	96
Guests	141
Total	297

Three tellers were appointed to count the votes for 1917 Officers and for Amendments to the Constitution. The tellers reported the following as the result of the ballot:

President—F. D. Egan.

First Vice President—C. A. Menk.

Second Vice President—S. C. Coey.

Treasurer—James Farrington.

Secretary—John F. Kelly.

Constitution to be amended as per Board of Directors recommendations that accompanied the ballots.

There was a total of 70 ballots cast.

Considerable discussion took place regarding the most desirable locality for holding the 1917 Convention. The consensus of opinion favored an eastern city. The cities of Philadelphia, Boston and Buffalo were mentioned but no definite decision was arrived at, and the matter was left to the discretion of the Board of Directors.

CENTRAL STATION POWER FOR STEEL MILLS

**By CENTRAL STATION POWER COMMITTEE, A.I. & S.E.E.
(C. S. LANKTON, Chairman)**

During the last few years, Central Station power has become an important factor in the consideration of the power problems of the steel plant.

This matter was discussed at the 1915 Convention of the Association, and it was thought advisable to appoint a committee to investigate to what extent the use of Central Station power could be made an advantageous factor in the development of economies in steel mill electrification.

The conclusion of the committee is that a study of the general advantages of Central Station service would develop the important facts to be considered in the determination of its use. This means broadly the determination of the facts regarding the conditions of operation in order to make comparison with steam or other forms of drive with electric drive using Central Station power.

To this end, the committee has outlined a paper consisting of various subjects, each subject being handled by individual members of the committee.

ADVANTAGES OF CENTRAL STATION POWER OVER STEEL PLANT GENERATION

(By D. B. RUSHMORE)

This problem is primarily an economical one; and the first requirement naturally is that the rates offered by the Central Station company shall be sufficiently low to be attractive. This does not mean, however, that the rate needs to be lower than the cost at which power can be generated at the steel plant, because there are so many other advantages

connected with purchased Central Station power, that even if the purchased power should cost a trifle more to generate it, it is generally considered preferable.

A large steel plant can generate its power cheaper than a small steel plant, and for the same reason it is evident that a central station of a capacity several times that of the power station which would be required for the steel plant, can produce power more economically than mill plant. This statement, of course, needs some modification, as there are many large steel plants where the waste gas obtained from the blast furnaces is used as fuel for generating the needed power, either directly in gas engines or burnt under boilers for generating steam to be used by steam turbines. Where the surplus of such waste gases is more than sufficient for the required power, it is hard to conceive that purchased power can be obtained at a lower rate than at which it can be produced. This refers especially to the larger steel plants, but there are a large number of plants which require a comparatively small amount of power and also a large number of plants which are purely rolling mills; that is, which purchase the raw material in the form of pig iron or ingots, and consequently do not have any blast furnaces from which any waste gases are obtained. It is with these two classes of plants that careful consideration should be given to the economies and advantages derived from purchased Central Station power.

There are several reasons why a large Central Station can generate power, and even distribute it for great distances, at a remarkably low cost. In the first place, its capacity makes it desirable to install generating units of the very largest size, which, of course, are exceedingly efficient, while, on the other hand, their cost per kilowatt is very low as compared with smaller units. Steam turbines are now under construction having a capacity several times that required for the average steel plant, and a reduction in the annual fixed charges on the station by using such enormous units is self-evident.

The second factor is the "diversity" of the different classes of load served, which results in a less investment in generating station equipment than would be required if these loads had to be supplied separately.

Besides the above, two reasons for the great economy obtained in a Central Station is the fact that its size warrants the employment of an operating force of the highest skill. A trained force of engineers gives constant attention to the smallest details of the operation, complete and very accurate records are kept and obsolete machinery is being constantly replaced by equipment of the latest and most efficient type. In short, the central station's sole object is the manufacture of power, cheap power, and the entire energy of the management, as well as the operating force, is devoted to this one point.

The load factor is a very important item, and the high load factor which many of the Central Stations have, obviously has a direct bearing on the low cost at which their power can be generated. Fortunately the load factor of steel mills is also fairly good, and equalizing devices are as a rule provided for reducing the momentary peak load inherent in a mill, so that as far as the load factor is concerned the steel mill load can be considered as having no detrimental effect on the Central Station load factor.

Granting that the power for a steel mill can be purchased from a Central Station company at an attractive figure, there are many other advantages which must be considered. All worry and care of an isolated plant is removed and the entire time of the superintendent and electrical engineer, etc., can be devoted to looking after the application of the hundreds or even thousands of motor equipments installed and improving the efficiency in this respect. Central Station service is considered to be the most efficient of all, provided as they are with ample reserve equipments, and reliability, of course, means greater production.

No one is more aware of the responsibilities involved in keeping the machinery moving than the steel mill engineer, as even a few minutes shut-down may mean damages of considerable magnitude. He may, therefore, argue that a system by which power has to be transmitted for some distance is more apt to interruptions than one where the plant is located at the mill. In response to this it may be said that improvements have been made in the design and construction of transmission lines, which makes them entirely reliable, much more so than is to be expected from the intricate

distribution lines within the plant itself. Of course, a larger number of circuits is always provided than are as a rule necessary to carry the desired amount of power, so should one line fail for some reason or other, the selective action of the protective switching equipment would automatically disconnect the same, and prevent the trouble from spreading further, thus insuring an uninterrupted service.

There are still many other advantages, as for example, the capital required for the construction of the power house can be used for the manufacturing plant proper, and additional power can be obtained quickly without any outlay for additions to a power house.

One more word, before concluding, in regard to the frequency. Many Central Station companies have only 60-cycle power to offer, and while 25 cycles is considered the generally accepted standard for steel mills, this mainly came about due to its advantages for gas engine driven generator units, large slow-speed induction motors and rotary converters. The improvements which have taken place during recent years in the design of the latter makes the 60-cycle converter now equally satisfactory to the 25-cycle, and it is interesting to note that the greater percentage of rotaries built today are of the 60-cycle type. It is true, however, that the slow speed 25-cycle induction motor is somewhat preferable, but with the type of steel mills where Central Station power is likely to be considered, it seems as if a higher speed motor with gearing or rope transmission would well answer the purpose. Sixty cycles admit more available motor speeds, and the cost of transformers and motors is lower for this frequency. There seems to be no reason therefore why 60 cycles should not prove entirely satisfactory for steel mill service, and the general trend is that this frequency will, in the not distant future, be the only recognized standard frequency.

POWER COSTS

(By R. L. BAKER)

The subject of Power Cost is so broad that the object of this discussion is to arrive at a definite basis of compari-

son in order to establish a cost system for power comparable with costs of other units of production of a similar nature procurable on the open market.

The cost of any commodity is relative to a certain standard and is determined by the total unit cost of each fractional part of the commodity, including the material and labor entering into the production of the unit; plus the cost of operating the business, including the physical plant or investment and the managerial expense of owners, officers, or directorate of the plant; plus a certain profit on the money invested in the business. The production of a unit of power is no different, as regards a definite cost per unit, than the production of nails, rails, or automobiles, if a standard unit is arrived at, but being used in the production of the marketable product of the company, its function is so limited and its market in the past has been so non-competitive that insufficient analysis is often made to accurately ascertain the unit cost.

On account of the generally popular use of electrical apparatus today the unit of power is well considered the kilowatt-hour, or its equivalent, and to assist in a standard of the cost of production, the following is an outline of a complete power plant cost system which covers practically every item entering into the unit.

ANALYSIS OF PRIVATE PLANT POWER COSTS

1. Fuel

- (a) Cost of fuel as delivered to department.

2. Salaries and Labor

- (a) Salaries of engineers and electricians (licensed)
- (b) Salaries of firemen
- (c) Salaries of water tender (licensed)
- (d) Wages to coal passers and coal unloaders
- (e) Wages to ash handlers.
- (f) Wages to boiler washers.
- (g) Wages to masons.
- (h) Wages to steam fitter
- (i) Wages of machinist (as required from other departments).

3. Repair Account

- (a) Boilers, including tubes, stoker parts, valves, piping and pipe coverings, fire brick, fire clay.
- (b) Engines and dynamos, including castings or forging

- parts, rings, brushes, conductors, etc.
- (c) Auxiliaries, including parts for feed water heaters, economizers, condensing equipment, pumping equipment, exciters, etc., coal and ash handling equipment.
- (d) Repairs to real estate, including power house building; hot wells, drain systems, cooling towers or ponds, condenser water mains, etc.
- 4. Removal of Ashes—Expense or credit on ash disposal.
- 5. Water—Cost from City of Pumping, plus cost of purification or treatment.
- 6. Oil.
- 7. Lamps for Power Department.
- 8. Tool Account.
- 9. Power and Light—Used in Power House.
- 10. Miscellaneous Supplies—Waste, Packing, etc.
- 11.—General Expense.
 - (a) Department apportionment of overhead expense on all non-productive labor itemized above. Usually 35 to 40% on actual cost of labor.
 - (b) Depreciation of equipment and plant—7% to 12½% on cost of plant.
 - (c) Interest on Investment—5% to 6%.
 - (d) Taxes.
 - (e) Insurance
 - (f) Rentals on space or real estate.
 - (g) Liability Insurance on employees.
- 12. Throw-over service (if any).

Now the trouble in accurately arriving at the amount chargeable to the items referred to above comes from the fact that the power department of the steel mill is so inter-related with other departments that there is some question in auditing the monthly expense, to definitely charge certain items of fuel and labor to the correct account. In the case of the steel mill where steam is usually used for many purposes besides the production of power, the item of fuel is perhaps the most unreliable of all. Too often the quantity of steam charged to power is distributed month by month for the period of a whole year on the basis of a short thermal test, or else estimated from the product of kilowatt-hours times the manufacturer's guarantee of the water-rate on the generating units for full load conditions. While the water-rate of the power generator is, doubtless, safe for the conditions specified by the manufacturer, one can readily see the fallacy in applying the same to a steel mill load with widely

varying steam characteristics, and intermittent load conditions, the usual long steam lines, etc. Therefore, considering the fact that steam chargeable to power is estimated and that the boiler room fuel and labor expense is divided proportional to the steam distribution along very similarly uncertain lines, it is not at all surprising that the average steel mill can tell little about the actual kilowatt-hour cost.

It would seem more care should be exercised in the distribution of the steam expense (fuel and labor) and that the power units stand more nearly their just proportion of the charges with less regard to the theoretical, and also a reasonable part of the usual 15% to 20% "unaccounted for losses" that regularly occur in the steam distribution balance sheets.

ESTIMATING RELATIVE COSTS OF CENTRAL STATION POWER AND PRIVATE PLANT POWER

In considering the substitution of purchased power for a private plant power, it is necessary to know as much as possible about the electrical load of the plant over a period of from one to three years, including total kilowatt-hours by months; graphic totalizing watt-hour records for typical days or months; load factor conditions, etc. In plants having modern totalizing watt-hour meters it is not expensive to install printing devices to procure load curves exactly as with Central Station metering. This method leaves none of the cost determining conditions for purchased power to be assumed and consequently insures dependable cost estimates. The Central Stations will be found more than willing to co-operate with the steel companies in determining the characteristics of the load, and in many cases they may be able to furnish and install the demand instruments required for the load record.

Knowing the cost per kilowatt-hour of the proposed purchased power, and the same for private plant power determined from the analysis given above, it is easy to decide on the advantageous product.

POWER COST CONCLUSIONS

The advantage of Central Station power from the cost standpoint will depend on the following points:

1. The ability to get a suitable power contract from the power company adapted to the peculiar requirements of a steel mill load.
2. The class of power generating equipment of the steel mill, whether modern or very old and obsolete.
3. The character of the steel mill business. Whether there is available blast furnace gas and waste heat in excess of that required for pre-heating and steam generation for purposes other than power; that might be used for steam generation to produce power.
4. The willingness of the steel mill management to change their present methods of using blast furnace gas and substitute the gas fuel for coal used for pre-heating, soaking pits, etc.
5. Whether the steel mill load is subject to wide seasonal and market demand fluctuations. With Central Station power the cost varies more nearly proportional to the mill production.
6. The cost of power is definitely fixed by contract and schedules are filed with Public Service Commissions, the tendency being to regularly decrease the rates as the business of the Central Station grows. The steel mill load usually representing high load-factor business, makes it very desirable Central Station business and offers the logical field for lowest industrial power rates.

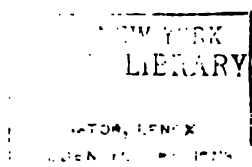
RATES AND CONTRACTS

(By E T. SELIG)

The rate schedule of twenty power companies furnishing power to steel mills have been obtained, and the principal parts of these schedules are shown by table No. 1. To permit comparisons the net resultant rate for 1,000-kilowatt and 5,000-kilowatt loads at 50% load factor were calculated which calculations gave the following results:

Net Rates per Kw-Hour 50% Load Factor.

	Maximum	Minimum	Average
1,000-kw. Demand	1.246c	0.700c	0.9417c
5,000-kw. Demand	1.060c	0.667c	0.8464c



NEW
SECTION

The divisions according to frequency are as follows:

60 Cycles	10
25 Cycles	9
25 or 60 cycles	3

Two power companies make a 10% lower rate for 25-cycle current than for 60-cycle current, due to their main source of water power being 25 cycles.

The power factor required, if any is specified, varies from 60% to 90%. Eight out of a total of eleven require 80% to 90%, three 60% to 75%, and eleven make no reference to power factor. It is noticeable, however, that the average rate of those having power factors specified are lower than those which ignore power factor.

The form of rate schedules are many and vary from flat rates per horse power year, regardless of energy consumption to those having complicated demand and energy rates and more complicated discounts. The majority of the schedules, however, have separate demand and energy charges, each of which charges may be in from one to six steps. For demand systems of charging, the peak period varies from one minute to sixty minutes, some are integrated peaks, some sustained peaks, while others do not state how the peak shall be determined.

Load factor and power factor play such important parts in the cost of manufacturing and distributing electric service, that minimum power costs cannot be obtained without taking these two factors into the calculations. The demand, including the effect of power factor upon it, is just as important a part of a proper rate schedule as is the energy charge. A mill, with a load factor of 70% and a power factor of 80% or better, can be served at very much less cost than another mill having a load factor of 35% and a power factor of 50% to 70%, and should not be required to pay an average rate that would be penalizing the mill with a good load for the sins of the mill having a poor load condition.

Rate schedules should be as simple as possible and avoid complicated systems of rates and discounts for varied load factors and consumptions. Where the mill can so adjust its operations as to permit keeping off the central station peak, there should be a lower rate than for peak service. Some of

the power companies reporting, charge only 50% of the peak demand rates for off peak service only.

While the difference in operating costs of the power companies will not permit of uniform rates for all, their costs all follow the same general lines and with different figures to fit different conditions, standard forms of rate schedules and contracts could easily be made to cover all companies. To this end we would recommend that in negotiations for Central Station power service and in order to obtain most favorable rates to the purchaser, it be insisted that the rate schedule be divided into demand charges and energy charges; that the demand be the average or integrated peak of 15 to 30 minutes duration; that the power factor be 80% with decrease or increase in the demand to be charged for accordingly as the power factor is above or below 80%; that the demand charges per kilowatt be in two or more steps; that the energy charges per kilowatt-hour be in two or more steps; that any excess demand occurring at other than the peak period of the power company's plant be charged at only one-half the demand charge normally applying for such excess if occurring on the power company's peak period. Long worded contracts made up principally of the words "whereas", "if", "and", etc. should be avoided in favor of short precise statements of what is to be furnished, how it is to be measured and what is to be paid, with no doubt as to what is expected of each party.

With rate schedules on the basis recommended, the mill engineer will obtain the benefits due to good operating conditions and not be obliged to pay for the poor conditions of another consumer's load.

CHARACTERISTICS OF STEEL PLANT LOADS

(By JOS. MCKINLEY)

The use of electric drive lends itself admirably to a close analysis of operating conditions. The various types of indicating, recording and graphic meters enables the user of electric power to accurately determine the distribution of power costs, while, in the case of other forms of power, the distribution is arrived at largely by arbitrary methods. The

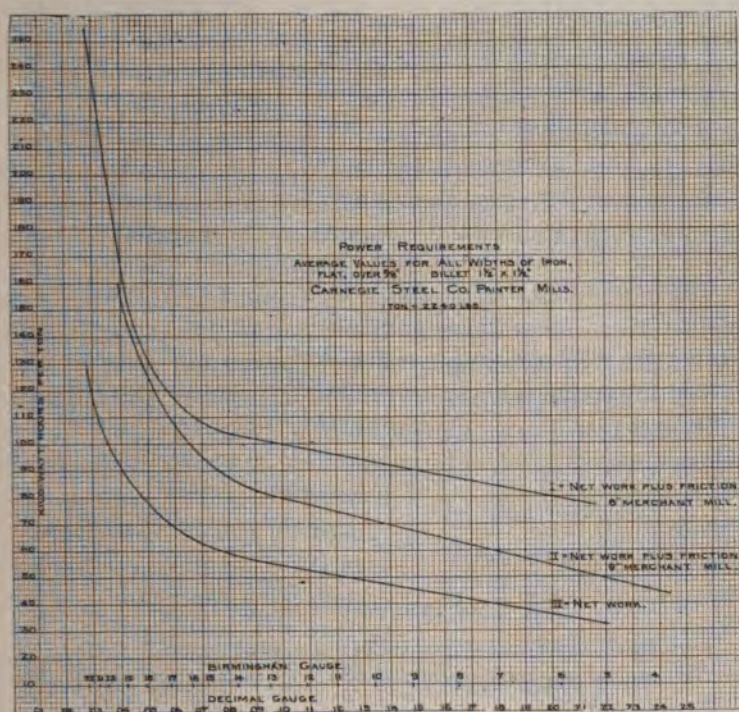


Fig. 1

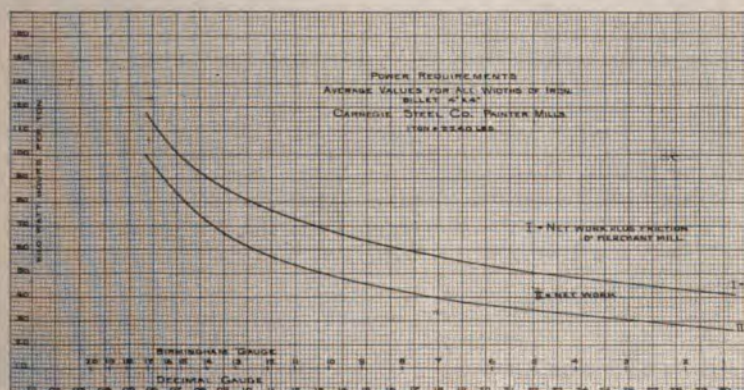


Fig. 2

use of such instruments also enables the user of electric power to collect engineering data such as capacity of machines, load curves, power requirements, maximum demands, power consumption and, in addition, providing a means of analysing the cycles of operation throughout the plant.

With such records, the Central Station can accurately determine the requirements of steel mills and negotiations for the sale of power are greatly facilitated.

The accompanying curves Fig. 1 and Fig. 2, have been compiled from data secured from motor driven mills and cover a period of two years. These curves are self explanatory and illustrate the analytical possibilities of motor drive.

In order to show the characteristics of the load in the steel mill industry, we have endeavored to secure load curves from a number of the large steel mills. These curves are reproduced in Fig. 3, and will be discussed in the order in which they are numbered.

CURVES NO. 1 AND NO. 2.

Curve No. 1 shows the characteristic a-c. load curve and curve No. 2 the d-c. load of the same mill and the total load of the plant being the sum of the two.

Total Kilowatt hrs. generated per year	34,141,500
Total kilowatt maximum demand	9,200
Load factor (Annual)	42.3%

Mill Drives—

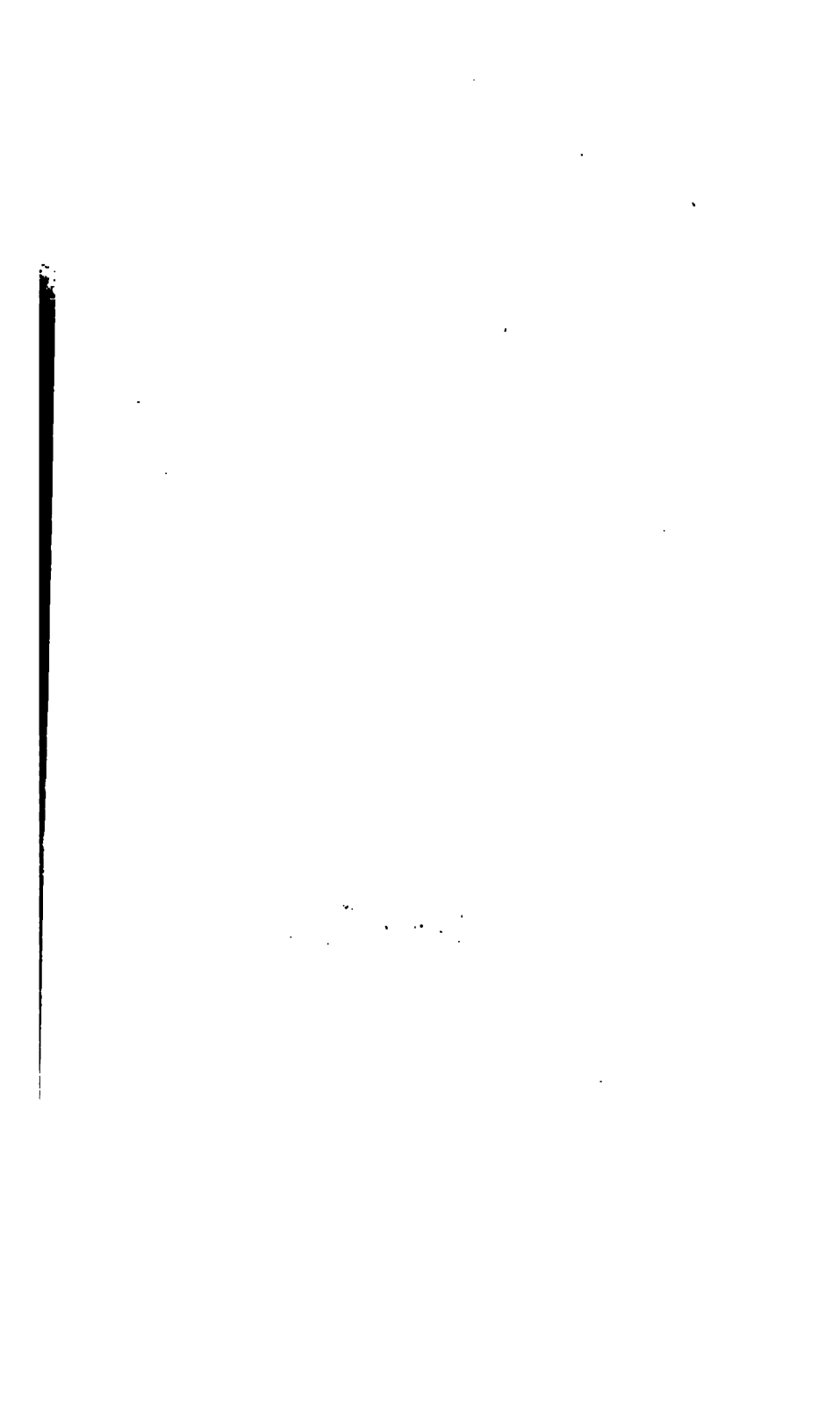
Number	
Horse power of each	1,500
Total horse power	3,000
Type of motor	Westinghouse "M", 220 volt, d-c.
Speed of motors	100-125 r.p.m.
Type of Drive	Direct Connected
Type of mill	Re-rolling light section Rail Mill
Speed of Mill	140 r.p.m.
Average kw-hrs. per ton of output of mill	60
Kilowatt maximum demand	1,100 kilowatts per mill
Kilowatt hours per year	3,088,800

Auxiliary Motors—

Total horse power	52,940
Total kilowatt hours per year	31,052,700
Kilowatt maximum demand	7,000

Character of Service—

250 volt, direct current for lighting and power.





6600 volt, 25 cycles, 3 phase, A.C. for transmission and synchronous motors.

220 volt, 25 cycles, 3 phase, A. C. for power.

110 volt, 25 cycles, Single-phase A. C. for lighting.

110 volt, 60 cycles, $\frac{1}{4}$ phase, A. C. for lighting.

CURVES NO. 3 AND NO. 4.

No. 3 is a characteristic total load curve of a steel mill using electric drive throughout and purchasing service from a central station. No. 4 is a characteristic load curve of one of the mills in this installation.

Total kilowatt hours per year	10,000,000
Total kilowatt maximum demand	2,240
Load Factor (Annual)	50.9%

Mill Drives—

Number	6
Total horse power	4,600
6—500 h.p.—425 r.p.m.	
2—800 h.p.—320 r.p.m.	

Type of motors—Wound rotor induction.

Type of drive—Rope and belt.

Type of mills—Merchant mill.

Kilowatt maximum demand	2,200
Kilowatt hours per year	9,821,000

Auxiliary Motors—

Total horse power	291
Total kilowatt hours per year	179,000

Character of Service—

440 volt, three phase, 60 cycle for mill motors.

220 volt, three phase, 60 cycle for auxiliary motors.

CURVE NO. 5.

Characteristic load curve of direct current plant in a large steel mill.

This direct current plant operates in conjunction with an alternating current plant, the output of the latter supplying service to a number of induction motors and to sub-stations in the most distant plants in the mill where it is converted into direct current.

Total kilowatt hours per year, d-c and a-c	21,602,000
Total kilowatt maximum demand, d-c and a-c.	4,950
Load factor	49.9%

Direct Current Motors—

Number of motors	1,399
Total horse power	39,880
Machinery operated:—Cranes, chargers, blowers, tables, compressors and machine foundries.	
Character of service: 250 volts.	

Alternating Current Motors—

Number of motors	20
Total horse power	3,200
Machinery operated: Hydraulic pumps, air compressors.	
Character of service: Three phase, 25 cycles, 6,600 volts.	

CURVE NO. 6.

Characteristic total load curve of a sheet mill using Central Station power throughout.

Total kilowatt hours per year	5,400,000
Total kilowatt maximum demand	1,075
Load factor (Annual)	57.3%

Mill Drive—

Number	1
Total horse power	1,400
Type of motor—Wound rotor induction	
Speed of motor—240 r.p.m.	
Type of drive—Gear	
Speed of mill—30 r.p.m.	
Type of mill—Sheet Mill, 4 Roughing mills, 6 Finishing mills, 2 Cold mills.	

Auxiliary Motors—

Horse power	300
-------------------	-----

Output—

30,000 tons per year. Average gauge	28
Average kilowatt hours per ton	180

Character of Service—

Three phase, 60 cycle, 2,300 volts for mill motors.
Three phase, 60 cycle, 220 volts for auxiliary motors.

CURVES NO. 7 AND NO. 8.

Characteristic curves of a cold Rolled Steel Plant using Central Station service. Curve No. 7 is a load curve of a-c. driven mills and auxiliary motors and curve No. 8 is a load curve in d-c. driven mills.

Total kilowatt hours per year	2,160,000
Total kilowatt maximum demand	480
Load factor	52

Mill Drive—**Alternating Current Drives**

Number of mills	11
Total horse power	850
Type of motors—Wound rotor induction.	
Type of drive—Gear	
Type of mills—Cold Roll Strip and Sheet.	

Direct Current Drives.

Number of mills	5
Total horse power	750

Type of motors—Each 150 horse power, adjustable speed.

Speed of motors—320 to 850 r.p.m.

Type of drive—Gear

Type of mill—Five stands arranged in tandem—12" cold strip continuous mill.

Service supplied through a 6 phase, 60 cycle rotary, 250 volt, d-c.

Kilowatt hours per year 624,000

Kilowatt maximum demand 200

Auxiliary Motors—

Number of motors 31

Total horse power 459

Character of Service—

440 volt 3 phase, 60 cycle for a-c. mills and auxiliary motors.

11000 volt, 3 phase, 60 cycle for rotary supplying d-c. mills.

CURVE NO. 9.

Characteristic load curve of a bar mill using Central Station power.

Total kilowatt hours per year 912,000

Kilowatt maximum demand 192

Load factor

Mill Drive—

Number 1

Total horse power 500

Type of Motors—Wound rotor induction.

Speed of motors 450 r.p.m.

Type of drive—Gear

Type of mill—16" bar.

Speed of mill 82 r.p.m

Kilowatt hours per year 912,000

Kilowatt maximum demand 192

Average kilowatt hours per ton 30

Character of Service—

440 volts, three phase, 60 cycles.

CURVE NO. 10.

Load curve on sheet mill using Central Station power.

Kilowatt hours per year 3,840,000

Kilowatt maximum demand 1,150

Load factor (Annual) 38.1%

Mill Drive—

Number 1

Horse power 1,000

Type of motors—Wound rotor induction.

Speed of motors 80 r.p.m.

Type of drive—Rope.

Type of mill—Sheet Mill, Stands, Roughing, Finishing,

Rolling 1.0 to 20 gauge 36" mill.

Speed of mill 30 r.p.m.

Character of Service—

6,600 volt, three phase, 25 cycle.

CURVES NOS. 11, 12 AND 13.

Curves Nos. 11, 12 and 13 have been obtained from a large steel mill having two power plants.

Curve No. 11—

This is the total load curve. There is required 1,600 kw. from the other plant in addition to the 6,000 kw. shown in curve No. 11.

Total horse power 31,711

Total kilowatt hours per year 38,102,337

Total kilowatt maximum demand 7,600

Load factor (Annual) 57.2%

Curve No. 12—

This shows the load curve in one plant when carrying auxiliary motors only. There is required 2,000 kw. from the other plants in addition to the 4,000 kw. shown in curve No. 12.

Auxiliary Motors—

Number 791

Total horse power 30,211

Total kilowatt hours per year 32,763,417

Kilowatt maximum demand 6,000

Load factor 62%

Curve No. 13—

Mill Drive

Number 1

Horse power 1,500

Type of motors—Two speed, double winding wound rotor induction.

Speed—162 and 182 r.p.m.

Type of drive—Geared to roughing stands and rope drive to intermediate and finishing stands.

Type of mill—Automatic rod mill.

Average kilowatt hours per ton 42.4

Kilowatt hours per year 5,338,920

Kilowatt maximum demand 1,300

CURVE NO. 14.

Load curve of steel mill showing that portion of its requirements supplied by its own power plant. Curve No. 9 shows that purchased by same company from a central station.

Total horse power supplied 3,250

Total kilowatt hours per year 2,421,000

Kilowatt maximum demand	572
Load factor	48.3%
Mill Drive—	
Number	1
Horse power	250
Type motor—Constant speed, compound wound.	
Speed	450 r.p.m.
Type of drive—Gear.	
Type of mill—10" bar mill.	
Speed	150 r.p.m.
Kilowatt maximum demand	200
Auxiliary Motors—	
Total horse power	3,000
Character of Service—	
250 volt, direct current.	

It will be seen from the above that the power requirements in steel mills are quite large, ranging from 1,000 to 10,000 kilowatts or more. A fair average will probably be in the neighborhood of 4,000 kilowatts. The load is characterized by large peaks. Where alternating-current service is used, the power factor will vary from approximately 65 to 80%. Large generating capacity is required to provide service of the proper regulation.

Table No. 2 has been compiled from data obtained from a number of steel mills and shows the generating capacity actually installed together with the connected load in motors and lighting.

Three important features to be considered by the Central Station in negotiations for this class of business are: 1st—The size of the installation; 2nd—The load factor, and 3rd—The diversity between the demand of this load and that of the Central Station. Securing this class of business permits the use of larger generating units of greater efficiency and lower cost per kilowatt of capacity. The improvement in load factor and diversity factor will reduce both the operating and overhead cost of generation. The curves given on Fig. 4 show the effect of the steel plant load on that of a large Central Station. Curve No. 1, typical steel plant load, is the summation of the load curves given on Fig. 3. Curve No. 2 is the present load curve of the Central Station and curve No. 3 is the summation of Nos. 1 and 2.

TABLE NO. 2—GENERATING CAPACITY ACTUALLY INSTALLED WITH CONNECTED LOAD.

Generating Capacity			Connected Load			Kw. Connected		Kw.-Hrs. per Year		
Total Kw.	No. Unit	Largest Unit	Motors		Light Kw.	Total Kw.	Kw. Generating per Kw. Connected	Total	Per Kw. Connected	
			No.	Total H. P.						
10400	8	3500	950	49790	750	44565	4.28	27,072,000		607
1650	3	550	202	6870	125	6171	3.74	4,325,000		700
9500	8	2500	730	26570	490	23871	2.51	38,725,000		1622
10650	8	2000	464	20640	490	18653	1.75	30,548,000		1638
6450	8	3000	1280	37790	750	34005	5.28	18,950,000		558
15400	11	2500	252	9787	146	8759	0.568	73,117,000		8350
400	1	400	72	1654	125	1590	3.95	68,000		43
2000	5	400	400	11525	563	10705	5.35	9,970,000		931
500	2	250	90	1947	84	1797	3.59	980,000		545
2200	4	550	201	4530	120	4106	1.87	5,432,000		1323
475	3	225	66	1131	56	1051	2.21	1,219,000		1159
250	2	200	8	135	55	174	0.697			
2150	4	550	398	13117	220	11763	5.45	7,594,000		646

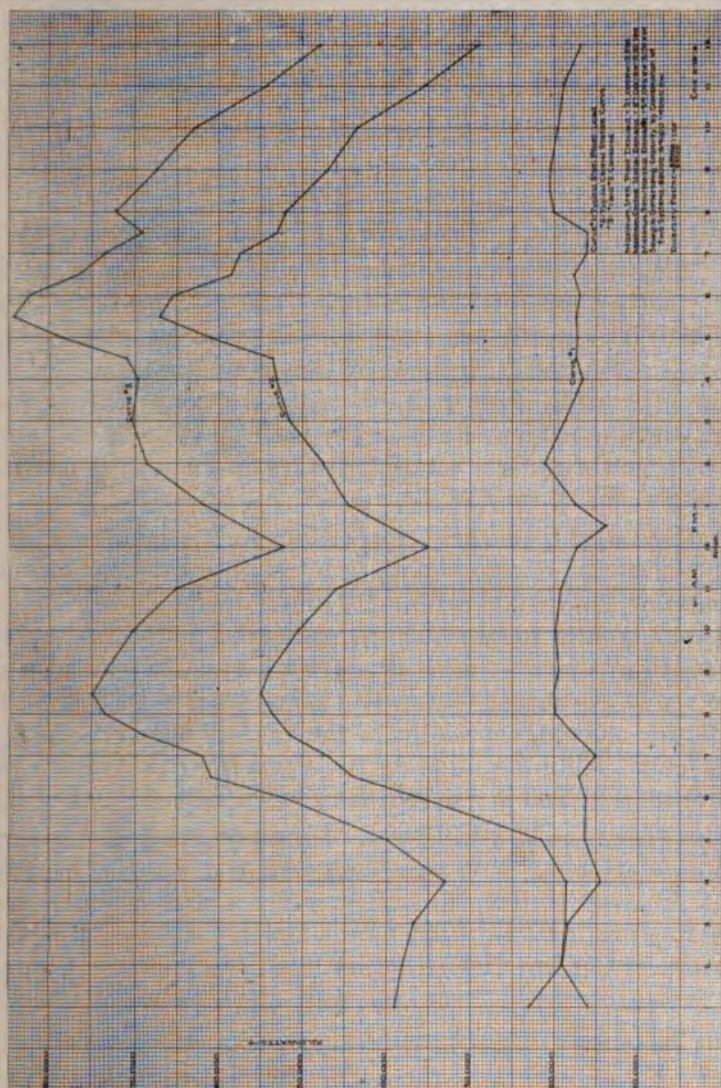


Fig. 4

This shows that the maximum steel plant demand is 21,000 kilowatts and occurs at 2 P. M. and that the Central Station maximum demand is 67,000 kilowatts and occurs at 5:30 P. M., and the maximum simultaneous demand being 84,000 kilowatts 5:30 P. M. This shows the diversity factor of 1.05.

STATISTICAL DATA

(By BRENT WILEY)

The use of purchased power by steel companies is rapidly increasing, the total as shown in Table 3 being more than 300,000,000 kw-hrs. per year. During the last two years approximately fifty per cent. of the motor units applied to main rolls were connected to Central Station companies' lines, and the percentage of power used by them as compared with power for the total of motors on main rolls has increased from 12 to 18%.

The number of companies using purchased power and the long period of many of the contracts is a strong recommendation, in particular from the standpoint of reliability. The power rate is favorable as compared with the cost of generating power, in a large majority of industrial plants. The use of purchased power often facilitates the completion of improvements, especially in the case of the remodelling of a plant, eliminates the extra supervision and care of a power station, and is a material factor in reducing first cost.

A reference to a further discussion of detail advantages of motor drive for main rolls of steel mills and use of Central Station power is given in a paper presented at the 1915 annual meeting, entitled "The Electrification of Steel Mills and the Use of Central Station Power."

Name of Steel Plant	Location	Power Company	Approx. H.P. per Year	Cycles	Character of Driven Machines	Contract
Seneca I. & N. Co.	Buff., N. Y.	Niles, Lothrop & Out. Pr. Co.	10,000,000	25	Two-Sheet Mill & Aux. Motors	1908
Lackawanna Steel Co.	Buff., N. Y.	Niles, Lothrop & Out. Pr. Co.	50,000,000	25	Main Roll & Aux. Motors	1907
Ontario I. & N. Co.	Welland, Ont.	Niles, Lothrop & Out. Pr. Co.	4,000,000	25	Main Roll & Aux. Motors	1908
Kansas City B. & N. Co.	Kansas City, Mo.	Empire City Elec. Lst. Co.	3,000,000	25	Main Roll & Aux. Motors	1913
Minnesota Steel Co.	Duluth, Minn.	Empire Northern Power Co.	4,000,000	25	Aux. Motors & Engine, Service	1915
St. Louis Screw Company	St. Louis, Mo.	St. Louis Elec. Light & Power Co.	2,000,000	25	Main Roll & Aux. Motors	1913
Siemens Manufacturing Co.	Leedsport, N. Y.	Leedsport Ls., H. & P. Co.	3,000,000	25	Main Roll & Aux. Motors	1906
Illinois Steel Co.	South Chicago, Ill.	Commonwealth Edison Co.	30,000,000	25	Main Roll & Aux. Motors	1914
Haletham Steel Co.	Syracuse, N. Y.	Syracuse Light Co.	1,500,000	25	M. R. & Aux. M. & Elec. Furnace	1906
Crescent Steel Co. of America	Syracuse, N. Y.	Syracuse Light Co.	1,500,000	25	Main Roll & Aux. Motors	1910
Laclede Steel Co.	Alton, Ill.	Alton Gas & Elec. Co.	6,000,000	25	Main Roll & Aux. Motors	1913
Nat. Enamel & Stamping Co.	St. Louis, Mo.	Union Gas & Elec. Co.	600,000	25	Aux. Motors	1914
Bethlehem Steel Co.	S. Bethlehem, Pa.	Lehigh Navigation Elec. Co.	35,000,000	25	Main Roll & Aux. Motors	1915
Maryland Steel Co.	Sparrows Pt., Md.	Con. Gas & Elec. Co.	20,000,000	25	Auxiliary Motors	1913
Apollo Steel Co.	Apollo, Penna.	(McCall's Ferry Plant)	5,000,000	60	Sheet Mill & Aux. Motors	1912
Carnegie Steel Co. (Pittsburgh Mills)	Pittsburgh, Pa.	Duquesne Light Co.	10,000,000	60	Main Roll & Aux. Motors	1911
United Steel Co.	Canton, Ohio	Canton Light & Power Co.	60,000,000	60	M. R. & Aux. M. Elec. Furnace	1912
Canton Sheet Steel Co.	Canton, Ohio	Canton Light & Power Co.	5,000,000	60	Sheet Mill & Aux. Motors	1915
Timken Roller Brg. Co.	Canton, Ohio	Canton Light & Power Co.	7,000,000	60	M. R. & Aux. M. Elec. Furnace	1915
Trumbull Steel Co.	Warren, Ohio	Trumbull Pub. Ser. Co.	7,500,000	60	Sheet M. & Aux. Motors	1916
Western Reserve Steel Co.	Warren, Ohio	Trumbull Pub. Ser. Co.	5,000,000	60	Sheet M. & Aux. Motors	1914
Empire Rolling Mill Co.	(Cleveland, Ohio)	Cleveland Elec. Illum. Co.	3,000,000	60	Sheet M. & Aux. Motors	1915
Unjon Nut Co.	(Cleveland, Ohio)	Cleveland Elec. Illum. Co.	4,000,000	60	Main Roll & Aux. Motors	1914
Central Steel Co.	Masillon, Ohio	Masillon Gas & Elec. Co.	9,000,000	60	Main Roll & Aux. Motors	1915
Feetris Drawn Steel Co.	Masillon, Ohio	Masillon Gas & Elec. Co.	1,000,000	60	Cold Drawing Motor	1915
Morris-Bailey Steel Co.	Wilson Sta., Pa.	Duquesne Light Co.	5,000,000	60	Cold Roll & Aux. Motor	1914
Standard Tin Plate Co.	Cannonsburg, Pa.	West Penn Traction Co.	7,000,000	60	Sheet Mill & Aux. Motor	1915
American Steel & Wire Co.	Baltimore, Md.	Comm. Gas & Elec. Co.	5,000,000	60	Aux. Motor	1913
Baltimore Sheet & Tube Co.	Baltimore, Md.	Comm. Gas & Elec. Co.	5,000,000	60	Sheet Mill & Aux. Motor	1916
Lewellyn Iron Works	Chattanooga, Tenn.	Chatt. & Tenn. R. Power Co.	7,000,000	50	Sheet Mill & Aux. Motor	1916
Chattanooga Steel Co.	Ashland, Ky.	Ohio Valley El. Ry. Co.	10,000,000	60	Main Roll & Aux. Motor	1916
Anland Iron & Min. Co.	Youngstown, Ohio	Youngstown & Shemango Ry.	10,000,000	60	Main Roll & Aux. Motors	1916
Shelby Tube Company	Elwood City, Pa.	Maloning & Shemango Ry.	7,500,000	60	Main Roll & Aux. Motors	1914
Union Rolling Mill Co.	Cleveland, Ohio	Cleveland Elec. Illum. Co.	4,200,000	60	Main Roll & Aux. Motors	1915
Gulf States Steel Co.	Alabama City, Ala.	Alabama Power Company	13,500,000	60	Main Roll & Aux. Motors	1914
Universal Rolling Mill Co.	Birmingham, Pa.	Duquesne Light Co.	1,000,000	60	Main Roll & Aux. Motors	1916
Wit-crow Steel Co.	Pittsburgh, Pa.	Duquesne Light Co.	1,000,000	60	Main Roll & Aux. Motors	1916
Monongahela I. & S. Co.	Pittsburgh, Pa.	Duquesne Light Co.	1,000,000	60	Main Roll & Aux. Motors	1916
Pennsylvania Steel Co.	Seaton, Pa.	York Haven Water & Pr. Co.	5,000,000	60	Main Roll & Aux. Motors	1908
Carpenster Steel Co.	Reading, Pa.	Metropolitan Elec. Co.	5,000,000	60	Auxiliary Motors	1911
Standard Steel Works	Burnham, Pa.	Penn. Central E. L. & P. Co.	5,000,000	60	Auxiliary Motors	1915
Central Iron & Steel Co.	Harrisburg, Pa.	Harrisburg Ls., H. & P. Co.	1,500,000	60	Auxiliary Motors	1910
Harrisburg Pipe & P. B. Co.	Harrisburg, Pa.	Harrisburg Ls., H. & P. Co.	5,000,000	60	Auxiliary Motors	1915
Midvale Steel Co.	Philadelphia, Pa.	Philadelphia Electric Co.	10,000,000	60	Auxiliary Motors	1916
Eastern Steel Co.	Pottsville, Pa.	Eastern Pa. E. L. & P. Co.	5,000,000	60	Main & Aux. Motors	1916
Phoenix Iron Works	Phoenixville, Pa.	Phila. & Suburban E. L. Co.	1,000,000	DC	Auxiliary Motors	1906
American I. & S. Man'g Co.	Reading, Pa.	Metropolitan Elec. Co.	3,000,000	60	Auxiliary Motors	1913
Atlantic Steel Co.	Atlanta, Ga.	Georgia Ry. & Power Co.	5,000,000	60	Main & Aux. Motors	1912
Tenn. Coal & R. R. Co.	Bessemer, Ala.	Alabama Power Co.	2,000,000	60	Auxiliary Motors	1915

*Frequency changes used to give 25 Cycle power for plant.

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APPLICATION OF CENTRAL STATION POWER TO STEEL MILLS

(By T. E. TYNES)

The result of the application of Central Station power to the production of steel are no different than the results obtained by power generated by the plant. That is to say the motors operating in the mills do not behave any differently when operating on the one kind of power than they do on the other, other things being equal.

In discussing the above subject the writer desires to bring to your attention two conditions of service, 1st—those wherein all the electric power used on the plant is purchased from the Central Station and 2nd, where part of the power is purchased and part is generated on the plant.

To meet those conditions makes the selection of the proper motor equipment an important problem, both from an operating and economic standpoint.

In all large modern Central Stations the power is generated as a-c. at a voltage considerably higher than is permissible for use around a plant. To transmit this power over long distances the generated voltage is further raised to several times above its initial value for the purpose of keeping down the transmission losses and investment charges.

At the receiving end of the transmission line this power must be re-transformed to at least two and generally three lower a-c. voltages, namely: 6600 or 2200, 440 or 220 and 110, and where d-c. power is used further transformation is required from a-c. to d-c. For rotaries a different a-c. voltage from those given above is required in order to get the proper d-c. voltage.

The 6600-volt or 2200-volt is used for driving the synchronous motor of the motor-generator sets, the large motors driving the mills and some of the larger auxiliaries, say from 100 h.p. up for the 6600-volt and 50 h.p. up for the 2200-volt for driving pumps, fans, blowers, etc., in those locations where these voltages can be used without endangering life and property.

For the remaining auxiliaries the a-c. voltage is further reduced to 440 or 220 volts, motors wound for these voltages have a wide range of application covering almost all

classes of service in the mill especially where constant speed characteristics are required.

For lighting 110-volt is generally used and transformed from either of the above voltages. Now in all of the above transformations a certain per cent. of the initial purchased power is lost, the magnitude of the losses being in the order of the motor-generator sets first, the rotary converter second, and transformers third and least.

In some contracts for Central Station power, the power paid for is that which is delivered to the high tension side of the transformers connected to the transmission lines, the power being measured on the low side of the transformers, the wattmeter readings on the low side being multiplied by a constant or multiplier which takes into account the transformer losses. In contracts of this class the purchaser pays for transformation losses. In other contracts the power paid for is that which is delivered on the low side of the stepdown transformers, the Power Company paying the losses of the first transformation, the purchaser paying for all others.

Generally it is not feasible to carry the high-tension transmission line voltage very far into the plant, so it is customary to install a transforming station on the edge of the plant and step down the line voltage to, say, 6600 or 2200 and transmit it to the various feeder stations in the plant either overhead or underground, the latter being preferable. This then brings in another loss, a transmission loss in addition to the transformer loss.

Let us consider for a moment what some of these losses may be.

The first losses occur in the transforming station and may vary from 2 to 3 per cent. say 2.5%. This leaves us then 97.5% of the power to transmit to the feeder station. The transmission losses will be from 5 to 10%, say 7.5%; this will leave us then 90.2% of our original power delivered to the feeder station. Here it is split up, part of it may go direct to the mills to drive the main rolls at the voltage at which it is received at the feeder station, namely 6600 or 2200 volts; some of the remaining power is further transformed to 440 or 220 volts for use in the induction or synchronous auxiliary a.c. drives. This will entail another 2.5%

loss, making available for these auxiliaries 87.9% of the power originally delivered for them. Another 3% will have to be deducted for that part which is transformed from 440 to 110 volts for lighting, leaving a net available of 85.3% of the 100% set aside for lighting. The question may be asked why not transform from 2200 to 110 rather than from 440 to 110, and save the 3% loss. The reason is that all mills do not have 2200 volts, but do have the 440 volts, and it is much safer carrying the 440 volts around than 2200. The balance of the power is to be converted into d-c. either by rotary converter or motor-generator set.

If rotaries are used about 3% will be lost in transformers supplying the rotaries, and 5% in the rotary itself, leaving a net power delivered to the d-c. bus-bars of 83.1% of the original, for use by the rotaries.

If motor-generator sets are used the losses of transformation will be about 12%, leaving a net power delivered to the bus-bars of 79.4% of the original power for the motor-generator sets. A summary of the losses is given in Table No. 4.

A study of the losses shown in Table No. 4 would indicate that in deciding on the motor equipment that that equipment should be selected which would entail the least losses to the power delivered to the motors. If this was followed out, without regard to other conditions, we would select 6600 or 2200 volt apparatus, but these are physical limitations and considerations of "Safety" that limit the use of those voltages, consequently only a relatively small number of the total motor equipment can use them.

Our next choice so far as efficiency goes, would be for the 440 or 220 volt a-c. auxiliaries. These can be used in almost all applications where d-c power is used, the exceptions being where variable speed and dynamic braking are required. The d-c. motors are so much better adapted for this class of service that the disadvantage of greater conversion loss is more than compensated for by their flexibility and adaptability.

The ratio of a-c. to d-c. used will vary greatly in different plants, depending on so many factors that no standard can be set.

TABLE No.4—LOSSES INCURRED IN DISTRIBUTING CENTRAL STATION POWER FROM RECEIVING STATION TO PLANT FEEDER STATION BUS BARS.

	Original Power Delivered by Transmission Line	Transformer Losses From Line To 6600, or 2200 V.	Transmission Losses From H. T. Transfr. To Feeder Station	Transfr. Losses 6600 or 2200 V. To 440 V.	Transfr. Losses 440 V to 110 V.	Rotary Losses	M. G. Set Losses	Net Power Delivered to Feeder Station Bus Bars.	Increase in Initial Cost of Power.
Mill Drives	100%	2.5%	7.5%					90.2%	11.9%
A. C. Auxiliaries	100%	2.5%	7.5%	2.5%				87.9%	13.8%
Lighting	100%	2.5%	7.5%	2.5%	8%			85.2%	17.4%
Rotary Converters	100%	2.5%	7.5%	2.5%		5%		83.1%	20.3%
M. G. Sets	100%	2.5%	7.5%				12%	79.4%	26%

In general, in those plants where power is purchased and where there are a large number of cranes and variable speed drives, it is safe to say the d-c. will predominate for auxiliaries probably in the ratio of 60% d-c. to 40% a-c., for voltages of 440 a-c. or less and 250 d-c.

The a-c. is suitable for driving fans, pumps, hot saws, cold saws, conveyors, straighteners, drill presses and possibly some mill tables. The writer does not favor a-c. motors for table drives, for the majority of them require a wound rotor type of motor which, as a rule, is more difficult to repair than a d-c. armature and the d-c. is better adapted to heavy table work.

The d-c. will be used for cranes, tables, charging storage batteries, electrolytic work and variable speed motors, especially those used for driving machine tools. The type of winding to use as to whether it should be series, shunt or compound wound, will depend on the nature of the load and the results sought. The classification of the applications to which the above windings should apply was discussed in a paper read before this association by Mr. R. B. Treat, at our annual convention held in Milwaukee, in 1912, and need not be gone into again at this time.

In general, would recommend the use of a-c. motors where constant speed, non-reversing conditions obtain and the d-c. where large starting torque, quick reversing and acceleration, variable speed or dynamic braking are required.

THE CENTRAL STATION AND THE ELECTRIC FURNACE

(By W. H. COGSWELL)

Electric power, as a heat producer, has been employed only to a limited extent up to the present time. It's high cost as compared with coal, gas or oil has naturally retarded development in its use. In recent years however, the improvements in generation and distribution of electrical power has reduced the gap between the costs of electric heat and heat produced direct from fuel to such an extent that the electric furnace engineers have been encouraged to apply their efforts toward the development of thermo-electric apparatus.

In the making of steel, there is a field susceptible of very broad development and the results to date are very gratifying. Of the three types of steel furnaces, viz: arc, induction and resistor, only the first two are worthy of commercial consideration and the arc type is best adopted to general application. This is well exemplified by the furnace building or in operation in this country amounting to approximately seventy (70) only two of which are of the induction type.

With but few exceptions, the power for operating these furnaces is purchased from central stations. As the central station supply is universally polyphase power at either 25 or 60 cycles, it is obviously essential that the electric furnace be designed to meet these service requirements. The reasons for the general adoption of this form of power are economic and will rule until some better method of generation and transmission is discovered. While in very small capacities, arc furnaces of single phase, single electrode design may be operated, it has been well established that as the capacity of the furnace is increased, the number of electrodes should also be increased. For example, a furnace requiring only 100 kw. may be operated as a single phase, single electrode furnace. But with a furnace requiring 300 kw., it is essential from the standpoint of good central station operation to employ polyphase power and from a furnace standpoint, to utilize either two or three electrodes depending on whether two or three phase service is utilized. When the power input reaches 1,000 kw. with a two-phase furnace, it is possible to increase the electrodes to four resulting in certain advantages both electrically and thermally. It is evident that unless the number of electrodes is increased in some relation to increased power input, the furnace voltage must be increased and there are certain very good reasons why that should be avoided.

Electrically, the arc furnace of proper design offers very desirable load for central stations. The power factor is favorable, 80% or better and the load curve may be maintained relatively smooth by means of automatic electrode control. The furnace transformers are designed with enough inherent reactance to take care of any short circuits that may take place in the melting down period.

Broadly speaking, it is safe to say that the development of the electric furnace in steel making is dependent upon the development of Central Station service. The two are inseparable.

DISCUSSION AT CHICAGO

W. T. Snyder: We certainly appreciate the value of this paper which has been contributed by the members of the Central Station Power Committee. If no other work had been done during the year than the Central Station Power Committee's, even that would make membership in this Association for each and every steel mill engineer desirable.

C. I. Crippen: The subject treated upon in this paper is of utmost importance to both parties, the Steel Mill and the Central Station; especially so at this time when mill capacities are being increased constantly; the Association is to be congratulated and the Committee complimented upon the excellent handling and forceful presentation of this very broad topic.

The question as to whether or not Central Station service shall be used for mill operation is, as has been pointed out in the paper, primarily one of economics but cases are very frequently found when the real and principal economics are not readily apparent until the plant has been operated by means of purchased power for a considerable time. Many examples could be offered where the management of a mill property, having a plant of its own in operation, has been very reluctant in entering into a contract for the purchase of the power requirement, perhaps the actual saving to be made is small and the purchaser quite doubtful at time of closing contract but almost without exception this same management soon comes to be a sincere advocate of Central Station service. Now why? Simply because of the many and various economics and savings which are incidental to an outside power supply; additional money, mental energy and time is available for increasing the earning capacity of the plant.

Every steel plant, operating a generating plant of any size, has a more or less elaborate system of cost keeping and it would seem that the method of obtaining these costs, their accuracy and meaning should be the subject of continued study by the entire management and the Electrical Engineer in particular. With these costs available direct comparisons can constantly be made with the costs of other plants of similar nature and with the costs for an equivalent block of power from the Central Station. It is readily apparent that these costs must be correct or false conclusions will result.

The choice of frequency is a matter of the highest importance to the steel plant engineer; as the paper brings out, the advantages of 25-cycle supply over that at 60 cycles have decreased until there is very little, if any, real gain in favor of the lower frequency. On the other hand the Central Station is, in general, definitely committed to the higher frequency because of large amounts of lighting load, hence the steel plant with 60 cycle apparatus will always be able to purchase current from Central Station in blocks of various sizes as occasions may require, without imposing the losses, capital changes and decreased factor of safety incident to frequency changes or their equivalent. The writer has knowledge of several cases where this difference in frequency has prevented the mills from entering into contracts with the Power Companies which would have been mutually advantageous at a common frequency.

Each year sees a more general adaptation of 60 cycles for all power purposes and it would therefore seem that plans for mill electrical apparatus should conform even at some material sacrifice.

Every new mill power plant projected should be well able to "earn to keep" over and above the cost of purchased power, that is capital invested in power plant must earn at least as much as a corresponding amount invested in steel making capacity with the cost of Central Station service the basis of comparison. From this it is apparent that a careful and continuous study of power costs in existing plants is necessary as the proper guide for estimating the costs in proposed plants.

The method employed in the paper, of making a composite load curve for a number of different plants and suggesting a uniform contract appears to be open to question as the variables entering into each case are so numerous and of such weight that averages would seem to be very uncertain. Briefly some of these points are as follows:

(1st) The relation of the mill load curve to that of the Central Station.

(a) Daily and annual load factors of both items.

(b) Time, shape and duration of both peaks.

(c) Possibility of rearranging the general form of either.

(2nd) The ratio of generating capacity required by mill to that of the Central Station.

(3rd) The relation power factor characteristics of both loads.

(4th) Cost of fuel or water power.

(5th) Transmission distances involved.

From a consideration of the above items and others closely related it appears that each principal case will have to be treated on its own merits at least for some time to come.

The use of electric energy for the production and refinement of steel by electric furnaces of various types is increasing rapidly and as is brought out in the paper, the power for the operation of these furnaces is principally supplied by Central Station; for this type of load the Central Station rates are usually low because of the high load factor and good power factor. This use of current for mill work is quite new and the uses to which the various furnaces are put covers such a wide range that the operating data cannot be compared directly in any number of cases. Generally speaking, however, electric furnace load is very desirable load for the Central Station and the steel plant has been able to put in furnaces of this type by buying their power without going to the expense and inconvenience of power plant additions. In fact, the Central Station may be given credit for a good share of the electric furnace development as rates have been made which would permit the experimentation necessary to develop the various types of furnaces.

Charles F. Uebelacker: I have read the advance copy of the Committee's report with both pleasure and profit. It presents the various phases of the steel mill side of the situation admirably. The Committee is to be congratulated on the completeness of the report.

Rather than directly discuss the points brought out in the report, I wish to place before you the elements which go to make up the cost to the power companies of providing electric service. This is touched upon briefly in the Committee's report, but perhaps a more full analysis of it may be of interest to those of you gentlemen who are considering the possibilities of central station power.

Broadly speaking, the cost of supplying electric service can be divided into two classes, namely, investment charges and operating charges.

To treat first on investment charges, namely, interest on capital invested, depreciation, taxes and insurance, I believe it will be accepted without argument that the vast majority of investment charges are proportional to the rate at which the power company is called upon to deliver electrical energy, namely, the number of units and size of units in its generating plant and to the carrying capacity of its transmission and distribution system.

The few slight exceptions which are not proportional to the rate of supplying energy (demand or peak) are investment in coal-storage facilities, investment in water purification plant, etc., which really are proportional to the energy-output of the plant (kilowatt hours), but constitute such a small portion of the investment that it is scarcely worth while to treat them separately.

Operating charges may be broadly divided into three classes:

1. Expenses which, for a given plant, are not influenced materially by either load (demand) or energy-output (kilowatt hours.)

To this class belong general officers' salaries and other executive expenses and most of the operating expenses usually classed under general expense.

2. Fixed operating expenses, such as engine and boiler room wages which are, for a given plant, proportional to

the number of units which must be operated; line maintenance and similar expenses.

These expenses vary with the demand on the plant even though that demand last for a short period during the day and are not materially influenced by the energy-output of the plant.

3. Those expenses which are directly influenced by the energy-output of the plant (kilowatt hours), namely, fuel, water expenses, and to a certain extent boiler maintenance.

In determining a rate which, to be sound, must be proportional to the cost, the power companies have then three different elements which must enter into the calculation.

1. A fixed expense (general expense, etc.,) which distributed over the entire demand on the power company's plant will decrease per unit of demand (kilowatt) as the demand on the plant increases.

2. Investment and operating expenses which vary directly with the demand, namely, interest, depreciation, etc., and engine-room wages, etc., as above mentioned. This will increase as the demand on the plant increases and the number or size of the units which must be operated to meet this demand increases and can be assumed for a given plant to be a constant expense per unit of demand (kilowatt).

3. Expenses which vary with the energy (kilowatt hour) output of the plant and which can be considered as constant for a given plant per unit of output (kilowatt hour).

In addition to the above three elements of expense, any sound business enterprise must consider the element of profit. This can be added to the expense above-outlined either as a per cent. return on the investment, in which case it will be added to the demand-charge, or a fixed profit per unit of energy-output (kilowatt hours), in which case it will be added to the energy charge.

It will be readily seen that the combination of the above elements will indicate a two-charge rate:

1. A charge per unit of maximum demand which a customer makes upon the power company, which charge, on account of the first element of expense above, should be decreased as the size of the customer's load increases.

2. A rate per unit of energy (kilowatt hours) actually taken by the customer which rate will remain constant for a given plant but will be decreased as the increase in demand on that plant requires the addition of more modern and economical apparatus.

It goes without saying that a contractor will make a closer bid on work where his remuneration is proportional to his expense, and it is equally evident that a power company, in order to make close figures on the delivery of electrical energy, must make its rate proportional to its expense. Whether this is done by making a straight energy charge decreasing as the load-factor increases or by making a two-charge rate, i. e. charge for demand plus a charge for energy, the principle underlying the rate must be the same if the power company is to stay in business.

W. T. Snyder: I believe it would be well, since the paper gives the views of the members of the Central Station Power Committee, to now call on some of our active and associate members that are not on that committee, and we can call on the members of the Central Station Power Committee later.

Noble Jones: The paper by the Central Station Power Committee deserves considerable credit, and may be taken as a boost for the use of purchased power in steel mills.

It is very true that purchased power is being used more extensively every day. No doubt this is due, in a great measure, to the activeness of the power companies' representatives, and the apparent inactiveness of steel plant engineers. The power company is ever ready with figures, which may be more or less confusing, giving costs to the prospective consumer. In many steel mill power plants it is difficult to properly segregate costs and the plant engineer is at a loss to know accurately his cost of generated current.

It would be very interesting if figures had been given of some of the various steel plants regarding their cost to generate current, so that a comparison could be made. I sincerely believe that several plants are generating current at a less cost than it could be bought for and there are several more plants which, with the addition of a few refinements that would effect economies, would be placed in the same class.

Is it not true that in order to get the low rate, we have to furnish an ideal load, that is, good power-factor and load-factor? Then why not install such apparatus in our own plants and get further economies? By generating current in our own plants we save some line loss and often transformer and frequency-changer loss, and in most cases have continuity of service, which may be of inestimable value, knowing, as I do, of one large power company having comparatively long lines, of the trouble experienced by them during electrical storms and the delays thus occurring; consideration to this should be given.

Much has been said of flattening of load curves, but if we go back a little further to our boiler room we find that the electric power plant also helps to give a more uniform and economical load there, together with the necessary direct steam-driven apparatus which in many plants would entail considerable expense to dispense with.

Regarding attendants necessary for the care of apparatus in the steel mill power plant, these in some cases may be done away with if power is purchased, but very frequently these same men look after other power equipment, such as pumps, compressors, etc. Therefore, they should be considered in comparison with any men required to care for converters, etc., if power is purchased. It has been stated that a personal "hobby" of the electrical engineer in the steel plant, of having his own plant, prejudiced him against purchased power. This may be true in some cases, but most of us have our company's interest at heart; and are doing our best to reduce costs wherever possible.

If our plant engineers can effect economies that will produce cheaper power than can be purchased, they should not be censored for their personal interest and pride in their work. After all, comparative costs of some of our self-producing power steel plants would be convincing, as well as instructive and interesting.

F. D. Egan: The adoption of central station power will result only from the economical advantages of such power. However, as the economy of central station power is determined not only by cost but also by its improvement of mill operations, so the economy of a competing power and

boiler plant in the mill can be determined only by careful consideration of its present and future status.

Where steel plants convert from iron to finished product, the use of central station power is very unlikely. However, in small plants converting from billets, slabs, etc., to finished product, a different set of conditions may make central station power very desirable. Even here, however, when the problem is carefully analyzed, cases are found where central station power will not be advantageous. As an example, take a plant that is using steam-driven blooming mills and finishing mills. Here, the cost of electrical power should not be considered as a separate item, for this power may add a steadying load to the boilers and so increase the overall efficiency of the entire plant. The ultimate problem, therefore, resolves itself to that of plant efficiency.

Where mills are electrically driven and all auxiliaries are the same, without doubt, the total load can be purchased more cheaply from a central station than it can be produced in the steel plant. However, this condition is due to the economies gained from the changed drives on the mills and not to the advantages of central station power.

In any steel plant that is arranged to allow for expansion, the engineer should carefully consider the effect of purchased power. Using bought power at twenty-five cycles would obviate the necessity of later changing the various drives or installing frequency changer. During the past year, the natural-gas shortage and the erection of by-product coke ovens has made this consideration very important. The use of coke-oven or producer gas in the open hearth results in very high stack temperatures and requires the installation of waste-heat boilers for good economy. Also, if during the plant's growth, a blast furnace is erected, the resulting waste-heat added to that of the waste-heat boilers would put the steel plant in a position to sell rather than purchase power.

A point which has always struck me in the matter of selling power to steel mills, is that the central station peaks come at seven o'clock in the morning, twelve o'clock at noon, and five to six-thirty in the evening. Anyone familiar with steel power plant load realizes that the shops and a great number of the machines in the finishing department slow up

at about 5:30 o'clock in the evening, and it is more a case of securing a load for the steel power plant than it is of purchased power. At that time the large power plant in the steel plant could help out the peak load of the central station, flattening the total load curves of the two plants materially, that is, the central station could thereby count on the standby capacity of the steel power plants, and in my mind in the future this will be tried out in the large districts of population.

The average steel mill load as indicated by the author's curve is very variable and characterized by large peaks. The inefficiency of such a load would favor centralization. However, properly balanced steel plant loads, showing total power curves similar to Fig. 1, can be obtained. Also, by proper balancing of synchronous machinery, unity rather than 80% power factor is practical.

During an average twenty-four hour run, the total load curve in our Midland plant showed continuous fluctuation of not over 250 kw., and the maximum and minimum output were respectively 3,200 and 1,800 kw. The average load throughout the day was fairly constant at 2,300 kw. and .97 P. F., the minimum load occurring at noon and the maximum at 6:40 P. M.

The plant consists of one 450-ton blast furnace, ten open hearth furnaces of 100 tons capacity, 40-inch blooming mill, 28-inch billet mill, Morgan continuous mill and 24-inch bar mill.

There is one point to which I wish to call attention and that is conclusion 4 under "Power Cost Conclusions," which says: "The willingness of the steel mill management to change their present methods of using blast furnace gas and substitute gas fuel for coal used for pre-heating, soaking pits, etc."

A person familiar with the two cases will realize that the heat value of blast furnace gas is 90 b.t.u., and if the gas is washed and delivered the sensible heat will be in the neighborhood of atmospheric temperature, while in the producer gas we have heat values of 135 to 140 b.t.u., and the sensible heat of 1700°F. near the producers, operating on a basis of 1500 lbs. of coal per hour.

The attempted change recommended by the Committee to use blast furnace gas will result in larger furnace checkers and higher stacks and increase the size of the building, and could not be adapted to the old pits installed.

While I have not taken up the question of steam distribution, the authors refer to it as the steam distribution in the average plant, further stating that we might find steel plants in which these methods are adopted. I feel that in a great number of the plants of the Steel Corporation and in a number of the independent steel plants, the subject of steam distribution and cost are thoroughly considered, that is, each boiler plant is fitted with a Venturi Meter in the boiler feed water line, individual steam flow meters on the boilers, all prime movers that are operating continuously, as turbines, blowing engines, etc., the steam load is checked with continuous recording steam flow meters.

We agree with the author that there is a standby loss, or an unaccounted for loss of 20%, 1% of which caused by blowing off and washing out boilers, loss of heat in transmission lines, etc. The steam distribution is made on the basis of the curves showing the accounted for consumption, and the total feed water supplied distributed on the percentage of the accounted for consumption, so that each unit shares in the so-called unaccounted for losses, and on that point I feel that not only a few, but a considerable number of the steam plants are going into this condition.

Another matter not clear to me, is the author's reference to the cheap cost of power at the blast furnace. Considering that the boiler plant is not given the gas for the production of steam at no cost, the production of steam by gas is properly accounted for, and the blast furnace is given credit for the corresponding weight of coal, at the cost of coal in that district. Coal, in our district, costs about \$1.80 per ton, and this means 75 cents to \$1.00 per ton on the iron.

I might say that our alternating current load runs the pumping stations, centrifugal pumps, air compressors, the straightening machines, the cutting-off machines, shears, and machinery of that type; in a number of cases where we use alternating current motors, we apply flywheels.

The alternating-current motor could be adapted with the use of flywheels to the average load, and kept within the range in question. Our plant does not have such a proportion of direct-current to alternating-current motors as to be unfavorable to the direct-current. In the blast furnace, open hearth furnace and blooming mill we will necessarily require direct-current machinery.

John C. Reed: I will call attention to the fact in using 60-cycle current through a frequency changer that care must be taken in endeavoring to tie two stations together through frequency changers. The regulation in our plant is such that we could not tie our station to a water power plant of equal size (both plants having about 10,000 kilowatts capacity) through a frequency changer of anything like 1,000 kilowatts capacity. The regulation is poor, and it is necessary to give them a certain amount of the load and run the two plants independently. Otherwise the load would crawl up on the frequency changer so as to exceed our guarantees and probably trip the breakers or endanger the frequency changer.

We pay for this current in accordance with the published rates of the water power company and in accordance with the rules of the Public Service Commission. There is no getting away from this and have no special contract whatsoever. In buying from a company of this kind, a lot of things must be taken into consideration. In this case, the power company is dependent on the Susquehanna River for its source of supply and it varies greatly throughout the year. At low water, it is a little short and at high water, the tail water backs up, so that it is a little short again. Then at other times, ice forms in the river, so it is necessary to carry its own reserve.

We have a cheap source of fuel besides the water power of the Susquehanna River, since it carries down large quantities of anthracite coal every year. This river flows right onto bed rock most of the way and the coal is pocketed in certain places along the river. It is easily sucked out with a sand sucker and delivered at the rate of 75 cents a ton—a fairly good grade of coal. This is the principal source of supply of the electric company and enables it to sell power

at a reasonable rate notwithstanding the fact that it does not have an up-to-date economical station.

W. T. Snyder: The point which Mr. Reed mentions in regard to the frequency changer brings out the importance of standardizing on 25 or 60 cycles in steel mill practice. It seems to me it would be well if that matter was given serious consideration. We have had warnings from time to time, and they seem to be getting stronger. If a mistake has been made, it seems corrective measures should be taken, and some definite recommendation from the Central Station Power Committee would help some. If Mr. Wiley would give in his statistical data the number of installations which have adopted 60-cycle, it would be of much value. I think it would be well to have stated what proportion of that addition is new plant and what proportion is additions to old plant load.

Paul H. Stambaugh: The subject under discussion at this session is, as has been shown by the subject matter submitted, one into which an almost unlimited number of factors enter. The value of any one factor on one side of the issue depends upon its corresponding complete consideration on the other side.

Considered as an economical issue, as referred to in that part of the paper presented covering "Advantages of Central Station Power Over Steel Mill Generation" exception may be taken to the statement, "Where the surplus of such waste gas is more than sufficient for the required power, it is hard to conceive that purchased power can be obtained at a lower rate than at which it can be produced." The issue in this case is not one primarily of advantageously producing power but rather advantageously disposing of gases. Steel mills having by-product or waste gas of any kind have no reason to expect that the gas supply will be at their disposal for power purposes in accord with the cycle of demands for power—the result being that all gas can not be utilized to best advantage. Would it not be well worth while for those confronting this problem, both steel mill men and central station men, to give some thought to a scheme by which every cubic foot of waste gas could be utilized at maximum efficiency?

Such a result might be accomplished by using the gas as fuel for a central station power house—the central station purchasing the gas from the steel mills and the mills in turn purchasing their electric energy from the central station. One result of such an arrangement would be a saving in coal, another would be combined diversity of gas supply and power supply. Such a scheme may be worthy of analysis.

The term "Power Cost," when central station power is referred to includes more than when used relative to power generated by the steel mill. A common basis of comparison may be agreed upon, but it is still a question when it comes to obtaining the common basis. This fact has undoubtedly had more to do toward retarding the introduction of central station power into the steel mill than any other one factor. In 75% of the cases where central station power is under consideration for steel mill operation, the real decision or rather the basis of the decision comes from the operating department, not the financial. An operating department endeavors to keep down operating expenses, it must do so. When a steel mill operator is asked to recommend the introduction of central station power, he is being asked to take over, as operating burden, a good sized item from capital account overhead. The result is that operators cannot be expected to concede much, overhead, depreciation, repairs, etc.

Analysis in this respect, of steel mills purchasing power will generally show that their operating and financial divisions are practically combined as one.

A comparison of rates offered by the different central station companies for steel mill power service is one of interest to all and the compiled data in the report gives us an idea of what might be done in this respect by going further into detail. In using this data, it must be remembered that two or more price things to be compared relative to one factor (in this case price per kw-hr.) must be definitely fixed relative to all other factors. This fact, however, is very easily overlooked. By reference to Table No. 1, we note a list—rates for kw-hr. Only two like conditions are specified, namely: billing demand and load factor. Were all other factors given proper consideration, the listed prices per kw-hr.

would be quite different. The fact of the matter is that true comparison cannot be made unless operating conditions and recording conditions are specified.

Power companies in general realize that loads such as furnished by steel mills can be handled very advantageously from their service lines and as a result considerable effort has been and is being made toward the taking on of such loads. Ultimately this question must present itself: "How far can the central station go with low price inducement and still maintain power service more dependable than other sources of supply?"

In a steel mill, having the power on and plenty of it, is of primary importance—cost being secondary. This is true regardless of source of supply.

S. C. Coey: This paper is certainly one that has required a tremendous amount of work to develop, and illustrates very forcibly the matter of the value of records. In many steel plants, records on steam generation and distribution have been of almost no value in the past, and it is only within the last few years that steel companies are coming to a realization of the value of getting these records in such shape that they will actually know what steam costs and what power costs.

Many plants have records extending over a number of years of the total number of kilowatts generated in their power stations, and I think the electrical end of steel plants has paid more attention to records than has the mechanical end.

At the present time a number of plants are installing meters and getting their steam costs more within the line of what it is actually costing them than has been the case previously, and in that way they are getting their power costs down to a figure that is really the true costs. It is only in this way that an accurate basis can be reached on which to make a comparison of the cost of buying power from the Central Station as compared with the cost of generating power.

Mr. Egan has remarked that about 20 per cent of the steam generated cannot be accounted for. I have been going into that for three or four years. I think we can account for all of the steam; but when we put Venturi meters

on the boiler feed water, and if we have duplex pumps and do not allow for the slippage of the pumps, and do not allow six or eight per cent. for blowing off, which is very low, and do not allow for losses in the transmission of steam, of course there is twenty per cent that is not accounted for, but we can get all these losses properly tabulated, we can get them in our records, and we can find out exactly what the power is costing in the present plant, with its own equipment. We can then make a comparison with the rates that the central station offers and get something that is of value.

The point is brought out in the paper that the present central station practice tends toward 60 cycles. Most of the large steel plants now installed have 25-cycle equipment, and it is going to mean a tremendous investment for these plants to be changed over to 60 cycles.

If we keep on 25-cycle equipment and are considering purchasing power from a central station, then we must always bear in mind that that loss, as represented in Mr. Tyne's Table No. 4, the loss in the frequency changer, is practically as much as in the motor generator set, so we have, on Mr. Tyne's basis of comparison, 25 per cent. to add to the cost of power before we get power on a comparative basis with an alternating-current bus-bar in the steel plant.

Another point that comes up in some localities is the fact that the steel plant may be developing a great deal more steam than the central station plant, and if that is generated on efficient steam-generating apparatus the cost of steam may well be lower than the cost of steam to the central station plant irrespective of the blast furnace gases or other waste-heat, and that is an important item in comparing the two costs.

R. Tschentscher: I have not come prepared to say anything definitely on the paper, but when the speaker presented the abstract I was impressed with two points, the first being that he seemed to be of the opinion that steel plants did not have a very clear conception of the cost of power. I checked off each one of the items given under the heading "Analysis of private plant power costs," and I find that records of all of the items mentioned are rigidly kept. I believe the cost of power generated, is within a very

few per cent. as accurate in the larger steel plants, at least, as in most of the central station plants.

When it comes to setting aside a certain amount for depreciation, obsolescence, interest on investment, and other regular fixed charges, I am not quite so sure that steel plants have been as liberal as central station plants in their estimates. But when it comes down to comparing power station cost as such, I believe at the present time the majority of the larger steel plants generating power have a pretty good idea of the cost of that power.

As has been indicated by Mr. Coey, in the last few years, and at the present time, I believe all the gas used, whether for making steam or in the gas engine direct, is charged for, and my personal experience has been that it is charged for at a pretty good rate. In any controversy as to what shall be a legitimate charge, the selling department has the edge in the steel business. The buyer of the blast furnace gas, whether he uses it in his gas engines or under his boilers, knows that he is required to use it, and I think most of us will admit that the producer of the pig iron is favored just a little bit in the matter of value of gas.

Another point that was mentioned was the question of reserve load. When the gentlemen who presented the paper referred to the matter, he particularly emphasized the fact that the steel plant operating gas engines must have large reserve power. I believe that central station men should become a little more conversant than they are with blast furnace gas-engine installations of recent make. Ten years ago, when the blast furnace gas-engine installations were first started, I think everyone will admit now that the dose was a little large and the industry suffered a little indigestion; but of late years there is no question, I believe, of obtaining absolutely reliable gas engines, reliable as compared with the steam turbine.

I think the capacity factor, as I call it; the relation between the amount of power actually generated and the amount of power which could be generated up to the capacity of the outfit, is about as high in many of the later installations of gas engines operating from blast furnace gas as it is in many of the steam turbine installations. I know

it runs as high as eighty per cent. based on a monthly basis, excluding any power generated on Sunday.

The impression is general, I believe, that central station power is more reliable than local plant generated power. In looking over the table of present users of central station power I see one or two, perhaps three, companies in the case of whom, I am quite sure, the question of reliability is not so very prominent. One must be very sure that the plant from which power is being purchased is a large plant and that its source of energy is reliable, and further, that its feeder connections from its power station to the local consuming plant, is also a very reliable installation.

I think the whole subject boils itself down to the fact that any plant having waste energy of any character whatsoever, whether it is waste heat from an open hearth furnace, whether it is blast furnace gas, whether it is by-product coke oven gas, or what not, must consider very seriously the use of every available b.t.u of that energy, in whatever form it exists, before considering the question of purchasing power.

There are many small plants, of course, that do not make pig iron, where there is no question whatever of the advisability of their purchasing power if they are in the vicinity of a reliable generation of power.

W. O. Oschmann: There are two points which might be mentioned, although the paper under discussion has brought out many points which govern the cost of power, both generated in steel plants and purchased power; however, in comparing the costs it might be mentioned that the power company makes its profit from the sale of the energy which it generates, while the steel company makes its profit from the steel sold. Therefore, it is necessary in the case of the power company to add a profit to the power generated. Also, the central station power charge carries the salaries of president, superintendents, clerks, also entire operating cost of office building, while in the steel works, as a rule, the salary of the superintendents and other expenses are a very small percentage of the charge to power generation, and are included in the product of the mill.

F. D. Egan: As to the point brought up by Mr. Coey, possibly he did not properly interpret my meaning. The

Central Station Power Committee spoke of what they called unaccounted for losses. That has reference to water evaporated by the Venturi Meter and tests taken in the different power stations. The difference between that and the power in the station would be what is referred to as unaccounted for losses. It would cover line losses, blow-offs, washouts, and any other means through which, in any manner whatever, there was a loss of heat. It is not something that we do not know, but it is simply something which was not measured in the test.

There are no continuous tests taken of steam lines, and it is a hard matter in long lines to get these losses other than by the measurement of heat input on the b.t.u. basis. When you run continuous curves on different stations the unaccounted for power is taken care of in the boiler plant distribution.

Robert W. Drake: In listening to this discussion, it occurs to me that there are many of us here who are operating plants smaller than those of the large steel mills. There should be, therefore, some consideration of interest in a brief discussion of central-station versus waste-heat power in such plants.

I am operating a plant on waste heat from reverberatory furnaces, several coal burning plants, and buying central station power also. The waste heat is made available by placing steam boilers between reverberatory furnaces and their stacks—about the only practical method in this type of plant.

It is not often that a waste heat plant of any type can be installed for anything near the cost per kilowatt of a standard coal generating station. This fact burdens the waste heat proposition with an added fixed charge which goes far toward balancing the cost of the coal saved. Then, as one of the previous speakers has mentioned, the peak of the waste heat supply, and the peak of the power demand seldom coincide, thus, there must be an auxiliary coal-fired boiler plant, still further increasing the fixed charges of the waste heat proposition; or equipment must be held ready at some other generating station, to carry part of the load during the valley of the waste heat supply. This reduces the load-factor of the other plant, whether it be a central station

or another privately owned plant. This extra cost due to lowered load-factor in another plant may not appear on the balance-sheets of the waste-heat plant, but it should be charged against it in making cost comparisons.

There is another evil against which we are all obliged to struggle. We put in an economical well-planned plant at the start, and then as the need for extension comes, the constant tendency is toward piece-meal extensions. Whether from financial considerations, or from space considerations, or through the need of haste, the directors generally wish to grant small appropriations for piece-meal extensions, of course this means a plant of small units, a plant which is ill-fitted to give the best generating efficiency. The power cost is increased in consequence. The progressive central stations are more often far-sighted in this respect.

There is one advantage in introducing central station power into a plant, if it is a comparatively small percentage of the total power used. When the cost of generation at one's own power plant is compared with the cost of purchased power, it is often found that the margin of saving between "home" generation and purchased power is very small, if just overhead expenses and fixed charges are charged off against the private plant, and obsolescence is considered. This offers a powerful incentive to a loyal engineering and operating force to further lower the cost of production at the private plant, both by more careful and intelligent operation and by general improvement in equipment. Such an incentive and month-by-month competition is a purely psychological effect, one may say, but it certainly shows on the balance sheet in a way which is very real.

D. B. Rushmore: It has been extremely interesting to listen to this discussion. Mr. Lankton is deserving of a great deal of thanks for the energy and persistency with which he has followed up the work necessary to collect the information embodied in this paper. It may be of interest, and I think it would be desirable at this time to second the suggestion that this matter may be on record, that the continuation of the work of the Committee is desired, and the asked for change of name from the "Central Station Power Committee" to the "Power Committee" will give it a larger scope for its work. That is really the subject, because, from

an engineering standpoint, the power problem in steel mills and central stations is not in reality divisible, but covers equally all of the three phases: generation, transmission and utilization.

It is interesting to note that the methods of figuring the cost of power are very far from being absolutely accepted. A sub-committee of the Standards Committee of the American Institute of Electrical Engineers has, as its chairman, one of the best known engineers in this country, Mr. Henry G. Stott, who is in charge of the work of attempting to standardize methods of figuring power costs. He and his committee are working in conjunction with representative committees from the National Electric Association, the American Railway Association and others, and it might be worthy of suggestion, that if Mr. Lankton's idea of enlarging the powers of this committee are carried out, that a sub-committee to handle this work might very nicely work in conjunction with Mr. Stott and his committee.

I will refer to the possible items which such a joint committee might well consider, two of the items which have been under discussion. The first is depreciation, which Mr. Stott does not agree exists. He says that maintenance and repairs will keep the plant up-to-date and that depreciation should go into obsolescence. The other item is figuring interest charges on the cost of power. A manufacturing company does not figure the interest on the investment into the cost of the product.

A word about standardization, of which this Association should be aware, and in which Mr. Lankton will probably be interested in carrying on the work of his committee. In connection with public utility work in this country, a very vital question has come up, as to who is going to standardize the practice of public utilities in regard to the action of the public service commissions and others, and such questions as voltage regulation, line construction and inductive interference, have to be considered. In England this problem has been worked out along certain lines as was brought to the attention of engineers in this country by Mr. Le Maistre, who came here in June to attend the meeting of the American Institute of Electrical Engineers and who also came out to Chicago and attended the large meeting

held under the auspices of the U. S. Bureau of Standards. In England, the industries, such as the steel industry, and the professional societies are organized together into one large standards committee with government representation. But the people are making their own specifications and are standardizing for themselves. In this country the situation has rather ran away with itself and the Bureau of Standards is taking the lead in this work.

Whether or not it is desirable to build up a government function which is controllable while it is small and may be uncontrollable when it gets very powerful, or whether it is better for the industries and the professional societies to go ahead very rapidly and do these things themselves in advance of the government, is a question worthy of quite serious consideration. The public service commissions are regulating public utilities, and just as surely manufacturing companies, industrial companies, such as the steel industries, are going to be regulated by the Federal Trade Commission, and electrical construction will come under regulation in just the same way.

It is quite interesting in a general way to realize that the tendency of the times is for mining and industrial companies to purchase power and this largely for the reason that early investments are disappointing at the moment. As now existing money invested in public utilities or in the manufacture of electrical energy is not as readily interested as money invested in steel making, mining and other industries, the Board of Directors are looking about for new lines for raising capital which can offer more inducements, and in a general way on the basis of buying central station power. Returns may in the future be restricted to the six per cent and undoubtedly industrials are going to have a long run before these restrictions are placed upon them, and the return at the present time, and for some time in the future, will be very much greater.

The Federal Trade Commission has made a statement which is rather interesting. The member from Chicago, who is now at the head of it, has said 80 per cent. of industrial concerns of the United States do not know the cost of the product they are turning out and as you probably know very active steps are now being taken to educate manufac-

turing companies along the lines of standardizing methods of estimating manufacturing costs, of which electricity is one.

The electrical engineer, without any doubt, is going to be the power engineer of the steel plant. Without doubt, electricity is going to play a greater part as one of the raw materials that goes into manufacture of steel products. You take the raw materials, add labor, add energy and add overhead, and you have the increased value and increased worth of the finished product.

In England, the suggestion made here this morning has been carried out, where the surplus gas from the blast furnaces is sold to the public utility company which supplies electricity to the steel mills, and it would seem as a general principle of economics as if it may be wise in some cases, where the manufacturing is carried on directly from the ore to the finished product, and where the energy in the gas is available, for a connection to be kept with large central stations whereby through an exchange of energy a surplus can be brought about.

Brent Wiley: During the last few years many plants have improved rapidly, including a number of additions in a comparatively short period.

It has been difficult for them to determine very far in advance just how extensive their additions would be as they depended on general market conditions, etc. As a consequence, the company is not able to give proper consideration to all the factors which would influence the most economical layout.

The above is particularly true in regard to the electric power plant. The original plant requirements may be such that small-sized units are suitable, but when improvements are considered it is difficult to determine what is the most economical method of enlarging the plant and to decide on the details.

The advantage of purchased power in this respect, has appealed to a great many steel companies as any addition to the load means lower cost of power and a general improvement in economy, and it is not necessary to outline and estimate on future developments.

In order, however, to determine the full value of electrification of the plant and future probable cost of purchased power, some of the larger companies have been acting on the plan of reviewing their conditions with the idea of laying out improvements that will cover a period of five to eight years. This method has the advantage of giving proper capitalization to the various points of each mill change as they will ultimately exist. For instance; the electrification of a mill may figure a saving in cost of operation of only 15 per cent. on the investment, but when estimated as a part of the entire mill electrification it will probably yield an increased return of double this amount. Thus it is well to consider a new extension from the standpoint of its relation to the plant improvement as a whole.

In the discussion of the paper on "Cost versus Upkeep of Direct Current Motors", it was stated that in order to obtain the desired quality of apparatus it was usually necessary for the electrical engineer to capitalize the points of superiority in detail. Such analysis work is essential in deciding the most advantageous apparatus for the application under consideration.

The same point is true in regard to the sale of central station power. The best proposition from the Central Station Company is assured only after the details of the load requirements are understood and appreciated by them. This emphasizes the value of records, for neither the Steel Company or the Central Station Company can give the proposition the best consideration until the power conditions are established.

The proportion of 25 and 60 cycle installations made recently, since Jan. 1st, 1915, has been 58 large 25-cycle motor drives purchased totaling 96,000 h.p., and 58 large 60-cycle units totaling 71,000 h.p. Previous to this period the ratio of the 60-cycle to the 25-cycle equipments on a total horse power basis is less than 20 per cent. and less than 15 per cent. regarding number of units. These figures show a very rapid increase in the use of 60 cycle apparatus.

T. E. Tynes: I think one of the most prominent and encouraging features brought out this morning in connection with this paper and the discussion is the fact that the central station engineers and the steel plant engineers are

getting closer together on this question of power. The steel plant people want as low a rate as they can get and the central station engineers want to give us that rate, consistent with the characteristics of the load which we demand from them. Two of the most important factors contributing to low rate are load-factor and power-factor, and if we can guarantee to the central station engineers a high load-factor and a high power-factor they will give us a good rate, very much better than if those factors are low.

Now, how can we give them these high load-factors and these high power-factors? There is only one way in which we can do it, and do it economically, and that is to utilize some of the waste-heat energy which usually goes to waste around the plant in large quantities. One method is the utilization of waste heat from open hearth furnaces; also utilization of exhaust steam from blooming mill and slabbing mill engines.

To show what can be done along this line, about five years ago in the plant with which the speaker is connected, we installed a mixed-pressure turbine utilizing low pressure steam that had formerly been going to waste. We were, in this way, enabled to bring our load-factor from 72 per cent. to 93 per cent, which gave us a much lower rate per kilowatt hour on the 93 per cent than on the 72 per cent. load factor. We were enabled by means of the savings obtained from this machine to pay for the whole installation in two years and a half. It was mutually beneficial to both parties; beneficial to us, and very much more so to the power company. They were glad to have us give them so good a load-factor.

I think if this fact was given consideration we would be able to get a very much better rate from the central stations than is usually the case where we buy on the ordinary load factor of the plant without trying to take some of their peaks.

R. L. Baker: There have been several remarks made in the discussion of the report which have been answered by other gentlemen in their remarks. I simply want to correct one or two impressions which seem to be prevalent. One of them is in connection with the analysis of power cost. This analysis is merely given with the idea of sug-

gesting a complete and standard basis by which to arrive at total power cost. As I said in reviewing the paper, the different mills have power accounts, and other accounts which overlap.

As to the question of competing with blast furnace gas. It was not our intention to state that we could not compete as big central stations with blast furnace gas on the cost basis. The question is rather that we cannot compete, taking everything into consideration. We are well aware that the electrical engineer has to pay for this gas in equivalent of coal, and that the cost per kilowatt hour is not materially different than a coal plant. Probably in a good many cases he would rather have coal, but as far as the steel mill itself is concerned, there is this waste gas that he is called upon to use in the production of power.

We feel that these are rather big problems, and they will take time to work out and the substitution of gas for every purpose of developing heat around the plant will not come at once, but there will sometime be a solution whereby the gas will be used for heat other than the generation of steam, or directly in the gas engine.

As to the other question brought out, in regard to Mr. Selig's analysis of the charge by different power stations for energy. It is not conclusive, of course, that all stations charge for energy on the basis of demand, consumption, or load factor. However, the large central stations are more inclined to look upon that as the most favorable charge both to the producer and consumer, whereas, of course, there are small central stations which make fixed, definite charges per kilowatt hour and pay little attention, perhaps, to the load factor.

DISCUSSION AT PITTSBURGH

G. C. Hecker: In reading over the report of the Central Station Power Committee, one of the things which came to my mind was the wide variation in the methods used in figuring the demand charge. They seem to vary from aver-

age daily one-minute peaks to one-hour integrated peaks. I have wondered if there could not be some standardization of the methods of calculating demand charges for various classes of service. I should also like to know how these peaks are measured. It must be a laborious job to obtain average or maximum one-minute peaks.

Brent Wiley: In regard to obtaining data on which to base the demand-charge, this is generally done by a meter that records the integrated load for any demand-period. This meter will indicate the amount, then drop to zero, and then integrate for the next period.

E. C. Stone: There is one point especially which I would like to bring out. This is the general proposition that a community can be most economically supplied with power, if all the power it uses is furnished from one central generating system. It is then possible to locate the power plants in the most advantageous positions with reference to coal and water supply and other operating economies, and to use the most economical generating units made, regardless of how great the capacity of such units may be, so that the cheapest possible production of energy is assured for the whole community.

Besides these advantages which the Central Station has over isolated plants, there are two other elements in the situation which operate to radically reduce the investment required when all the energy used by a community is supplied from one power system. The first of these is the amount of capacity which must be installed as spare to insure continuous service in the event of breakdown. For example, a 10,000-kw. load would be more economically taken care of by the installation of two 10,000-kw. turbo-generators than three 5,000-k.w. units, after the lower steam consumption of the larger units had been allowed for. Such a station would thus have installed 100% excess generating capacity as insurance, whereas with the entire power supply of a district served from one system, the total load would be so much in excess of the capacity of the largest unit, that one or possibly two spare units would only be 10% to 25% of the total capacity of the system. The saving in the latter instance is obvious.

The other element referred to is the "diversity" of the demands for energy of the different consumers connected to a central station system. For example, the business man when in his office is burning his lights there; when he leaves the office he puts out the office lights and takes the elevator; he later takes the street car and finally reaches his home and turns on the lights. Thus, he requires power successively in his office, in the elevator, on the street car and at home, but not at any two points at the same time. Hence, if all of this energy is supplied from one source the same equipment will be used successively to supply the power at the different points. This means that the maximum load carried at one time on the Central Station system is very much lower than the sum of the maximum loads taken by the different consumers connected to the system. In Pittsburgh, the Central Station's peak occurs at 5:30 P. M. At that time, although the energy demand of the street railways system is at its maximum, that of both commercial and residence consumers is considerably below maximum, so that if all of these different classes of service had to be supplied from different generating systems, thirty-five to fifty per cent. more generating capacity would be required than is now needed where all are served from one system, and if each individual consumer were on an individual power plant five to ten times greater capacity would be required.

On the chart (Fig. 4) showing the effect of a large steel plant load on a central station system, it will be noted that the mill load will require only 17,000 kw. of the Central Station's capacity since that is the load taken at 5:30 P. M. the time of the system peak; whereas if the mill load was to be carried on a separate plant the capacity of the plant would have to be at least equal to the mill's maximum demand, which is 21,000 kw. and which occurs at 2:00 P. M. The saving in plant capacity in this case, by using the Central Station, is 4,000 kw. or almost 25% of the mill's maximum load.

Again, in Table No. 2, showing the generating capacity and connected load actually installed at a number of steel mills, the generating capacity, which is made up of units of 100 to 15,000 kw. each, totals up to 62,000 kw. If it so happened that all of these mills were in one district so that

they could be served from one Central Station, they could all be served from not over 50,000 kw. of capacity, including the necessary spare, as against 62,000 kw. actually installed. I believe it is conservative to estimate the total investment of these various generating plants at \$6,250,000. The same service supplied from 50,000 kw. of Central Station equipment, including the transmission, would not require an investment, I think, of more than \$3,250,000, which means that if all of these mills happened to be in one territory \$3,000,000 of investment could be saved by supplying their own power from the Central Station system. Of course, the mills in question are not all in one district, but the idea that I want to bring out is the enormous saving in investment effected by supplying all the power needed in a district from one system.

The desirability of using electrical energy in the form in which it is produced cannot be too strongly emphasized.

As is well known, electrical energy can be most economically generated in the form of alternating-current. The two standard frequencies in this country are 25 and 60 cycles, the tendency at the present time being distinctly towards the latter.

A change in the frequency of the alternating-current supplied or its conversion to direct-current will involve an additional investment of some 25% to 30% of the cost of the generating plant and the only thing gained by such investment will be the form of energy obtained. The benefit derived from the change in "form" must obviously be very definite in order to justify the large increase in investment to obtain it.

There are times when the flexibility of control of direct current or the lower cost of low speed 25-cycle motors will warrant changes in the "form" of energy, but each case should be carefully studied and decided strictly on its merits.

The cost of a motor goes up as its speed goes down and for very low-speed motors the increase in cost is as rapid as the decrease in speed. Low-speed motors are generally used in rolling mills because of the low speed of the mills, so that a very large investment is frequently made for motors. I understand that gears are not satisfactory at present but the highest economy undoubtedly points to high-speed mo-

tors, connected to the mill by step down gears, and it is to be hoped that the gear manufacturers will work out this problem satisfactorily so that the excessive investment in slow-speed motors can be saved.

Low power-factor is another source of investment cost. A power-factor less than unity increases the investment in all electrical equipment, including generators, lines, transformers, motors, and decreases the overall efficiency. Hence anything that can be done to improve power-factor is advantageous if it does not cost more than it saves.

H. C. Eddy: As the paper was abstracted from a central station point of view, I made notes as the various items were brought out, and some of those have already been discussed. There are one or two points I would like to contribute. The first one is, that the question of source of power and the way it makes the wheels go round is not an abstruse, deep, technical problem at all; it is commercial; it is a question of dollars and cents. The function of the steel mill electrical engineer is to provide power and operate the mill at the lowest possible cost to the company. The function of the central station is to assist him wherever possible. They can't assist him if he approaches the subject with a mental attitude that it is impossible for them to help him, and with the idea that the central station is there to exact all that they possibly can for the service that they render, irrespective of any other consideration.

The central station has the same problems to meet as the steel mill, and the reverse of that is quite true. Low power cost is made up of a number of items; first, we will say, production cost. I mean by that, the cost of manufacturing and putting energy on the bus-bars; that is composed of labor, fuel and miscellaneous supplies. The probabilities are there are many steel plants in this country that can beat many central stations in production costs, and that is particularly true when they have had their own cheap fuel in the way of coal, which they own and which they mine, or if they have a cheap supply of gas.

On this foundation, viz: production cost, there goes another set of costs, which are familiarly termed overhead costs, or fixed charges, sometimes translated into maximum demand cost. The steel mill has just exactly the same

fundamental elements of cost that the central station has; the trouble has been to get the steel men to admit it. Some of them will and some say they do not know what it is; that element of cost is applied by their accounting department, and the figures are not available. Coming back then to the point that Mr. Stone mentioned, which was that for an equal service, the central station requires less apparatus. You all know—those of you who operate your own plants, that your generating capacity is less than your connected load. This can be carried a step further and the generating capacity which would be required by the central power plant to replace generating capacity in isolated plants in a given district would be less than the sum total of the isolated plants so replaced; so that if an exact accounting is made of all the elements of cost, the central station makes its greatest showing in the reduction of the investment cost. Now that amounts to more than generating cost, and perhaps, as I have said before, is not within the limits of the engineering department to control, but it is something that all the steel companies, or any other manufacturer, for that matter, must face, if he is going to face the issue squarely; and that brings me to this thought: That the best and most permanent business association for both the central station and for the purchaser of power is that which is arrived at through co-operation of both buyer and seller.

Someone has raised the question of maximum demand. I presume everyone of you is familiar with that elementary problem as to why a maximum, and why is a charge made for it. That charge, of course, covers the investment in equipment which must be supplied to meet the requirements of the purchaser. The man who requires at some time a maximum load of 10,000 kw. and only uses on an average, 2500 kw., is not so good a customer, of course, as the man who occasionally requires 5,000 kw. and usually takes 4,000 kw. That is elementary; if you will turn back several years in the files of the American Institute of Electrical Engineers, you will find a very exhaustive and interesting article by Mr. H. G. Stott on the cost of power. You will find a diagram there which shows the difference in the cost of power between 10 per cent. load factor and 90 per cent. You will find that the curve of production cost is a very flat

curve. It costs comparatively little more to produce a kilowatt at 10% load factor than at 90%; but if you will look at the investment cost curve you will find something vastly different. The investment cost per kw-hr. at low load factor is many times that at from 75% to 90%; the sum total of the two represents the total cost. Now, I daresay, some of you gentlemen who are in a central station district have some desirable load on which the central station would be delighted to make a low rate. If you ask them to take an undesirable load, naturally they have to protect themselves against increased cost occasioned by added charges. Basic conditions are the same in the operation of your own plants; if you have an undesirable load factor it means you have a large amount of station capacity (which means dollars) not utilized, except for very short periods in the twenty-four hours. I did not come prepared to discuss this matter and have been suggesting these points rather at random, but they are, I believe, of prime importance, and emphasize the one big point I would like to make, that is the necessity for full, frank and free discussion between the engineers of both parties to a bargain, and the necessity of co-operation, in order that both may derive the greatest possible advantage from our business relations.

There is just one more point I would like to touch on, and that is this question of length of maximum-demand period. There is a great diversity of opinion among central stations. One operator will consider that one-minute peak is the proper basis; another man says 10; another 15, 20, 30, or an hour. The longer the period over which the demand is taken, the nearer you come to the average condition, and investment is not made on average conditions but upon maximum conditions. One operator will fix 30 minutes, perhaps, because he figures he will carry his average load on certain generating capacity, which capacity will carry an overload equal to the sum total of the maximum demand made on it for 30 minutes. Another station's condition may be such that would be very hazardous. For my own part, and speaking on behalf of my company, we have felt it was unwise to carry that maximum demand period to a point where we were constantly calling on a reserve or overload capacity on the units in service which were suffi-

cient for ordinary requirements. As I said before, there is a difference of opinion among operators. I think that will eventually work itself out, and we will all be more nearly in accordance as our experience increases.

J. S. Jenks: I look at central station service for a steel mill, or any other mill, differently from the way some do, from the fact that I might say "service" includes many things which others never think of. For instance, we consider that service is not only supplying power, but it is delivering to the customer every service possible for an organization such as a large power company has, to give each and every consumer the advantage of the best skilled talent to be secured in the country and the highest grade mechanics.

In connection with central station power, the consumer is justly entitled to the service of each and every employe of the power company. The consumer pays their salaries and is entitled to whatever he can get in the way of service. I do not think it is sufficient for any power company to simply connect its wires to those of a customer and consider as long as it supplies energy through its wires its obligation ceases. There are many things the average customer,—in fact, 99 out of 100,—knows little of in connection with service, and I think it is the duty of every central station to see that the customer gets the maximum return for the dollar he pays out. That can only be done by having a corps of engineers, mechanics and operators, who continually call on and instruct, test, clean, or do anything that might be necessary to keep the customer's service and his plant in operation. Now, I do not mean to impress upon you the fact, or lead you to believe, that the power company should do all your cleaning or repairing, but there are times when every customer gets into a corner, when emergencies happen that a power company can help them out in many ways.

The concern with which I am connected employs a large staff who regularly call on every customer, and it is those men's duty to make calls and render some service. Our instructions to those visitors are to render some service and if they can't find anything else, to clean up a bit, because they find the customer permits a little dirt.

Very few using central station service give the apparatus the care they do to their own plant. They feel because it is central station, its performance will go on indefinitely. Apparatus that is supplied by central station companies should receive as much care as your own. The service men should see that the apparatus is kept clean; they can properly instruct the attendant of that apparatus. They should if necessary, call in any higher talent to overcome difficulties that arise.

Let me cite a few instances: Once a small machine shop had a motor that had been operating for some five years and required a new commutator every year. As soon as our service man found it in that condition he asked about it and they said, "That is the way that motor always did." They regularly put on a commutator every year. The service man said, "Can't I look at it?" The only time of shut down was on Sunday, so the service man went on Sunday and found one field pole was reversed, which he corrected, then tried out the machine and went back Monday morning. It was a machine designed by a competent maker that had slipped up. The customer was highly pleased, and did not understand how it was that the commutator about to be replaced would last several years. Another case came to my attention within a week. Quite a large steel plant ran into mechanical difficulty, telephoned in for help, and within fifteen minutes there was a corps of competent mechanics on the way to repair a coupling. It was a matter of service. We felt the mill should be kept running, and we made a temporary repair until we could replace it. Such service as that will go a long way towards making central station power satisfactory to the customer.

It is quite true that under some circumstances, service of that kind is not really necessary. We have met some narrow-minded fellows who thought we made inroads on their jobs. In fact, we have found, and I could cite a number of cases, where some engineers who have been the most willing and have met the public service company half way and asked for help when they needed it, are the fellows who have not stood still. I could cite you a case of a young man who went into a steel mill purchasing central station power and the successful service he gave there was remarkable.

He was picked up by some associates and taken as a member of a firm to reorganize another steel plant. It was largely due to the fact that he wasn't narrow. He did not claim to know it all, but with his helping us and our helping him was able to prove that he was worth while, and they felt they needed someone worth while.

A few years ago we had quite a depression. We all became exercised as to what our load would do during this depression, when many plants shut down entirely. We were surprised to find our load going up. We had started with a great many concerns by supplying them their excess power. When the depression came along, the customer learned that he could shut down his plant and buy what little power he required far below the cost of operating his own plant; invariably those customers who had been buying a small excess immediately started to buy all their power, and instead of output dropping off, it soared very astonishingly.

There has been some little discussion on the matter of demand, the demand-period or peak-period. I, myself, am in favor of short peak, because the maximum benefit that can be derived by any central station from power units is through diversity. Apparatus generally has overload capacity of 50% for one to two hours. If you sell a customer short peaks, you will have capacity for more customers; large peaks of two hours, for instance. If you grant a customer a two-hour peak period, he may consume your whole peak capacity; while if you sell on a short peak, you can supply a great many more customers and supply many more peaks; your investment is less and your cost to consumer will be less. It merely resolves itself down to make a consumer as desirable as possible. It has been my experience that it costs very little to consumer to make his load desirable.

I can cite a steel mill buying power on one-minute peaks. When it started out, its peaks were long and high. After a little study, arrangements were made whereby signals were placed in the mill, and in a short time the mill hands learned that by working to the signals they could get out greater tonnage by keeping the mill working at a higher load-factor and reduced peaks. The consumer lowered his peaks between 25 and 30 per cent., hence reduced cost of power, and

at a capital cost of \$12. You can understand that \$12 won't go very far towards a central station, step-up station, transmission line and step-down station, and I think you will agree with me that under such conditions, it behooves the consumer to make his load-factor as high as possible to get benefit of better rate. If all consumers did such a thing, it would make much better load for the central station, and would make the central station a very much better service to the consumer and it would result in material reduction in the cost of power.

The matter of power-factor is another case where the consumer can at a very small cost save the power company a very large cost, and if the power company is wide-awake, it will allow the consumer benefits for such service. I think you will find a majority of the central station companies are granting from two to ten per cent. for power-factor correction or line potential regulation. If you regulate your load for line potential, not necessarily running high power-factor at all times, but when loads are heaviest, which may mean overloading your machine for a short period and as soon as load is off, letting it drop back, you will give the power company a load which is much more desirable, and the power company can sell such service at less money. We are giving 5 per cent. discount for line or power-factor adjustment; this can be obtained very readily by installing synchronous apparatus of very slight over-capacity. You can readily understand that it is much cheaper for a customer to install a liberal capacity himself to take care of the power factor condition rather than have the power company provide capacity in generators, step-up transformers, transmission lines, step-down transformers or synchronous condensers.

It is quite true that waste gases cut quite a considerable figure in the cost of power. Just a few days ago, a case came to my attention where a large steel plant put in a very elaborate generating plant to use waste gases, but this summer its power has been curtailed due to a shortage of water. A short time ago, it was taking water from a distance, which also had failed, and its product was cut down to less than twenty-five per cent. That is a condition which could have been avoided had they taken service from central station, as central stations are invariably located where they

have adequate supply of water, whereas, steel companies have to locate frequently where the supply of water is inadequate.

Another item which has been mentioned is the terminal loss of the plant. I am familiar with a large steel plant in this vicinity which had a very great investment in copper, due to transmitting the power from its power station to various parts of the mill and the conditions became so bad that they were driven to an investment of some \$15,000 for a battery to maintain regulation in some of the more distant parts of the mill; while on the other hand I can cite you where power is delivered to four or five parts of the mill, which eliminates all low-voltage losses and saves very considerable investment.

Jas. Farrington: In regard to steel plants selling excess power, we have arranged with power companies to sell them any power we desire at 10 per cent. less than their average cost to us.

W. T. Snyder: In Table No. 3, giving the frequencies of the different contracts that have been made, out of 50 contracts here we notice 14 are 25-cycle; only two of those contracts were made during the year 1915, and none since 1915. Out of the total of 50, 35 contracts were for 60-cycle power. Of those 35, 20 were made in 1915 and 1916, which plainly indicates the trend towards what is to be the standard frequency. It brings up the question of what should be done on new extensions—whether we should continue the 25-cycle or change over to 60-cycle. Are we likely to have a quantity of obsolete 25-cycle apparatus on our hands in a few years after manufacturers have standardized on 60-cycle?

THE ADVANTAGES OF MODERN TYPES OF DIRECT CURRENT MACHINES

By DAVID HALL

The modern type of direct-current machine with commutating poles and compensating windings, and the necessary field connections, present a certain complication as compared with the plain non-commutating pole machine. The user of such a machine naturally asks: "why the additional complication; what am I getting in the modern type machine that I did not get in the old type; is the machine any cheaper, or does it perform any better; what can be accomplished with the modern design that was impossible with the old design?" The user may even think that his old machine is as good as can be desired, and for its particular application this may be true; yet when the cost of the old machine is considered, he will find that the modern machine is much cheaper. The materials are not cheaper, the copper and the steel are more expensive, yet the design of the modern machine is such that more output and better performance can be obtained from the same amount of material. This is due entirely to improvements in proportions and design, and the direct-current machine of today is widely different in many details of construction from the direct-current machine of ten years ago.

The user is primarily interested in cost and performance. In other words, he wants a machine to satisfactorily perform a given duty, and that machine which fulfills this condition and costs the least is his natural selection. Simplification is, of course, desirable; in fact it must never be lost sight of in the design of any class of machinery, and no piece of machinery is well-designed until it possesses the maximum simplicity, embodying the desired characteristics.

To obtain certain characteristics may require additional parts, and one of the functions of design is to decide whether the additional parts and complications are justified by the improved operation.

Before endeavoring to set forth the advantages or disadvantages of any particular construction or type of machine, let us consider the electrical machine in its most elementary form. Let us endeavor to get a simple fundamental conception on which we can build up, so as to obtain finally a machine best suited for any particular conditions of operation. A simple view of an electrical machine makes any of its functions and possibilities very evident. Hence we are justified in spending some time in forming fundamental conceptions and fixing these conceptions clearly in the mind. In order to do this, we must necessarily review old ideas, but in the end we hope to obtain a clearer conception of the fundamentals.

Let us look upon the machine as a certain mass of steel and a certain mass of copper, the mass of steel is to provide a path for magnetic flux, and the mass of copper is to provide a path for electric currents. In this conception, we have the two main elements; **flux** capacity and **current** capacity. These two elements constitute the back-bone of the machine. Further deductions as to what can be obtained from a given machine will all revert to these two factors.

FLUX CAPACITY

In rotating electrical machines, we are primarily interested in the total flux, which passes through the air gap between the stator and the rotar, and which is cut during rotation by the belt of copper conductors, distributed on the armature. As a measure of this flux capacity we have the **gap area**, that is, the circumference of the armature multiplied by the length of the armature core. If we let D = diameter of armature, and L = length of armature, the flux is proportional to D multiplied by L .

While the flux capacity for a unit area of gap is not the same for all machines, yet for a given class of machine the air gap area can be considered a fairly accurate measure of the flux capacity, and it is therefore evident that the flux capacity of any machine increases directly as the diameter

of the rotor increases, and directly as the length of the rotor increases. Thus, flux capacity may be looked upon as air gap area, and any changes which increases or decreases the air gap area would cause a corresponding increase or decrease in flux capacity. The steel above the air gap and below the air gap may be looked upon as a necessary evil—simply a carrier to make possible the air gap flux, as also may the field copper be looked upon as a necessary evil—a means simply of producing the air gap flux.

CURRENT CAPACITY

Next let us get a conception of current capacity. We can look at the conductors adjacent to the air gap as a belt, having a definite area of cross section; that is, the total copper section is equal to the cross-section of the copper in one slot, multiplied by the number of slots. If we look upon this total cross-section as the area of one wire, we have a measure of the ampere-wire capacity, that is, the current which all these conductors would be capable of carrying when connected in parallel. If this cylindrical belt of conductors be considered as one large wire, then the total current which is carried represents the ampere wire capacity of the winding. The ampere wire capacity is entirely dependent on this section of the copper, hence, other things being equal, the section will increase directly as the diameter of the armature increases, and it is independent of the length of the armature; that is, armature wire capacity is proportional to D . While the ampere capacity for a unit area of copper is not the same for all machines, yet for a given class of machines the copper section may be considered a fairly accurate measure of the ampere wire capacity.

With flux capacity, proportional to gap area, and ampere wire capacity proportional to copper section, we now have a measure of a given machine—whether it be a motor or a generator, an a-c. or a d-c., and whether it stands still or rotates. We have a mental picture of a cylindrical copper cage; the total cross-section of all of the bars of this cage is a measure of the ampere wire capacity, and increasing the length of the cage does not change the ampere-wire capacity. It is evident that the ampere capacity of these wires will depend on how well they are ventilated; conse-

quently for the same temperature rise, the better the ventilation, the more current can be carried by a given section of copper. Hence, the necessity of well ventilated armature. With a given ventilation, a given diameter of armature and a given section of armature winding, the ampere wire capacity is fixed. That is, if we consider all the conductors surrounding the armature as a single wire, there is sufficient copper section for a definite number of amperes. However, if we so connect these armature conductors as to use one half of them to carry current through from the front of the armature to the back, and the other half to carry the current from the back of the armature to the front, we will have doubled the number of conductors, and have halved the number of amperes, but the product of the amperes and the conductors will remain a constant; that is what we have called the ampere wire capacity. We may have on the same armature 1000 amps. and one wire, or we may have 1 amp. and 1000 wires.

We will now deal with these three factors, flux, amperes, and wires. The flux capacity is a constant for a given size armature, and the ampere wire capacity is a constant, but the amperes can be reduced and the wires increased by properly connecting the wires on the armature. So far, we have not mentioned output, or speed. It is evident that at zero speed, we have zero output. If the armature is rotated, the voltage generated will be dependent on the flux, the speed, and the number of wires in series, and as the output is dependent on the product of voltage and amperes, we see that output must be proportional to flux, speed, amperes and wires, and it is the variation of these four factors which constitutes the many ratings which are obtainable from a given mass of steel and copper.

OUTPUT=Flux x Speed x Amperes x Wires x Constant. From this simple formula a number of facts are easily observed. If a maximum output is to be obtained from an armature of given dimensions, the flux must be made maximum, and the ampere wires must be made maximum. On a given armature, there is only a certain space available for flux and wires. It is not essential that an armature of given dimensions and for a given rating be worked always at the same flux, but when the flux is fixed, the wires will also

become fixed, and either of these may be changed, but they must change together. If the flux is increased, the wires will be decreased, and vice versa. Hence it is that from the same diameter and length of armature a machine of a given rating may be designed with a relatively large amount of flux and a small number of ampere wires or on the other hand, the machine may be made with relatively small amount of flux and a large number of ampere wires. The former machine will require a large amount of steel and a small amount of copper; the latter machine the reverse. The weight of the machine is determined principally by the amount of steel, the former machine will be a heavy machine, as compared with the latter. Thus it is that two different designs for a given rating may be made; one might be called the steel machine, that is, the heavy machine; the other might be called a copper machine, that is, a light machine. These different relative proportions of steel and copper constitute different performances and cost; and it is around these factors that designs may be said to revolve.

In observing the above formula and considering that the flux, as it enters the air gap, is perpendicular to the wires on the armature, one might suggest that the output could easily be increased by making the armature slots narrow and deep instead of wide and shallow. This argument is entirely true, and the slots are made as deep as can be permitted, taking all other factors into consideration. As deep slots increase the self-induction due to current reversal and as at high speeds deep conductors may introduce other losses, it is found that slow speed machines contain deep slots, while high speed machines contain relatively shallow slots. The high speed machine ventilates better than the low speed machine, and consequently the copper can be worked at a higher density. As a rule, the high speed machine will have a higher self induction, and in order to obtain good inherent commutation, it generally becomes advisable to use relatively shallow slots in high speed machines. From the standpoint of efficiency, these relative proportions are also desirable; that is, slow speed machines require a large amount of copper, and high speed machines can be made with relatively less copper.

From the same skeleton of a machine, there may be obtained many outputs—depending on the speed. For example, from the same skeleton, there can be obtained 100 kw. at 100 r.p.m., 200 kw. at 200 r.p.m., and 1000 kw. at 1000 r.p.m. This is, of course, speaking generally, as regards the flux and ampere wires. For changes in voltage, changes in the number of poles will become necessary. If a machine is properly constructed to give 100 kw., at 100 volts, when running at 100 r.p.m., this same machine will give 200 kw. at 200 volts when running at 200 r.p.m., and 1000 kw. at 1000 volts when running at 1000 r.p.m., if there were not other limitations, both mechanical and electrical, which prevent this simple procedure being applied over a very wide range of rating, and speeds. As the voltage obtained from a given skeleton is dependent on the flux, speed and wires, if the speed is set, the wires will have to be increased in order to increase the voltage; and as the product of amperes and wires is a constant, the wires can only be increased by reducing the ampere capacity; hence it is that the same skeleton of a machine may be used to give 100 kw., 100 volts, 1000 amps. at 100 r.p.m., and also 100 kw., 200 volts, 500 amps., at 100 r.p.m. The latter machine has twice the number of wires and twice the voltage, but one-half the ampere capacity. To emphasize the above, we would say that the capacity of a given skeleton is proportional to its speed and the voltage at a given speed is proportional to the wires connected in series on the armature.

So far, we have not considered how a machine is affected by a change in amperes. Generally speaking, if the total amperes are large, it is desirable to have relatively large number of paths in the armature. Hence, on large current, direct current machines, a large number of poles are used, and on small current, high voltage machines, a small number of poles constitute the best design.

Increasing the length of a given armature increases the flux capacity, but it does not increase the ampere wire capacity. Hence, the output of the armature will increase directly with its length. Increasing the diameter of an armature increases both the flux capacity and the ampere wire capacity. Hence, the output of an armature increases directly with the square of the diameter. Combining these two statements, we conclude that the output of a given armature

is proportional to the square of its diameter multiplied by its length.

Output is proportional to D^2L , where D = diameter of the armature in inches and L = length of armature in inches.

$$Kw. = D^2 \times L \times \text{r.p.m} \times \text{output factor.}$$

The aim of the designer is to obtain a high output factor, that is, to obtain a large output for a given armature diameter and given length of armature. To put this in other words, the designer endeavors to so proportion the machine as to get maximum output at the minimum cost. One way of accomplishing this is to ventilate the various parts so as to enable the maximum watts to be dissipated with least amount of heating. For example, the armature core may have a liberal number of air ducts, and the armature spider may be designed to easily admit the air into the core.

It may be of interest to analyze the above formula a little more closely, and see on what the output factor depends. The following proof will show that this output factor represents what may be called the loading factor of the armature, or, in other words, the magnetic flux per inch of length, and the armature ampere wires per inch of armature diameter.

Let F = No. of lines of flux per inch of diameter per inch of length of armature.

A = Armature ampere wires per inch of armature dia.

Total flux = $F \times D \times L$.

As the cutting of 10^8 magnetic lines per second by one conductor generates one volt, and as each conductor or wire on the armature cuts the total air gap flux once in one revolution, we can write the expression for the voltage generated.

$$\text{Volts} = \frac{F \times D \times L}{10^8} \times \frac{\text{R.P.M.}}{60} \times \frac{\text{Wires}}{\text{Circuits}}$$

In this formulae, $\frac{\text{wires}}{\text{circuits}}$ represents the total number

of armature conductors divided by the number of circuits in the armature, or it is the number of wires in series on the armature. For example, the six-pole machine may have the winding so connected to the commutator bars as to give six paths in the armature. That is what is generally called a multiple armature winding, and the ends of an armature coil

connect to adjacent commutator bars. This type of winding is used in practically all large d-c. machines, that is, the number of circuits in the armature is the same as the number of poles. The armature winding may be so connected to the commutator as to give only two paths in the armature. The latter winding would be called a two-circuit winding. With the same number of commutator bars and the same number of turns per coil, the six-circuit winding will give one-third as many volts as the two-circuit winding, but it would have three times the current capacity. It will be observed that the ampere wire capacity is the same in both windings. If the six-circuit winding gives 100 volts, and 3000 amps., the two-circuit winding would give 300 volts and 1000 amps.

Multiplying both sides of the above equation by amperes, we obtain:

$$\begin{aligned} \text{Volts x Amps.} &= \frac{F \times D \times L}{10^8} \times \frac{\text{R.P.M.}}{60} \times \frac{\text{Wires}}{\text{Circuits}} \times \\ &\quad \text{Amps. per wire x Circuits.} \\ &= \frac{F \times D \times L}{10^8} \times \frac{\text{R.P.M.}}{60} \times \text{Amps. Wires.} \\ &= \frac{F \times D \times L}{10^8} \times \frac{\text{R.P.M.}}{60} \times A \times D. \\ &\quad D^2 \times L \times \text{R.P.M.} \times \frac{(F \times A)}{(60 \times 10^8)} \end{aligned}$$

In this equation, we have an expression for the total watts of the machine. The term in the parentheses is the output factor. The output which is obtainable from a given size armature at a given speed depends upon the flux per inch and the ampere wires per inch. The higher these two factors are worked, the more will be the output from a given armature. These two factors have their limits. If the flux is too high a large amount of field copper is required, at a consequent increase in cost. Also, if the flux density in the armature teeth and core is made high, the iron loss will be high. The actual loss in the iron will increase much faster than the density increases. In slow speed machines, the

iron loss is usually very small because of the low frequency; consequently, this does not become the limiting factor, but in high speed machines, that is, machines of 30 cycles or more, the iron loss begins to be a considerable factor in the total losses, and must be kept down in order to make high efficiencies possible.

The ampere-wire loading of the machine, as has been observed, is a direct factor in the output; hence, the desirability of making this high. The current density which can be used in the armature conductor will depend on the ventilation, the permissible heating and the efficiency which must be obtained. The section of copper which can be put on a given armature will depend on the size and shape of the slots. As flux capacity and ampere-wire capacity are equally important in obtaining output and as the increase of one means the decrease of the other, the design becomes a compromise. If the armature slots are made narrow and deep, they interfere the least with the available section of iron for the flux. As has long been known, armatures with narrow deep slots have more self-induction due to current reversal than armatures with wide shallow slots, and while the capacity of such armatures from the heating stand-point, as shown by our formulae, may be very large, the commutation limit might be much lower. The above formulae have in no way taken commutation into consideration, and if there is any one element in a direct-current machine which is more important than all other elements, it is commutation. We thus arrive at the real reason for adopting some special means for taking care of commutation.

For many years, previous to their general use, commutating poles were well-known, but the requirements imposed by the users of electrical machines were being met in a reasonably satisfactory manner with the old non-commutating-pole designs. Necessity for machines with greater overload capacity, for machines of high speed, for wide range, variable speed motors, for generators capable of operating over a wide range of voltage, for machines which would stand reversal either mechanically, electrically or both, has led to the general introduction of special means for insuring good commutation. This has not come without the addition

of some new parts, and without a certain relative degree of complication, but the general improvement in operation since the introduction of commutating poles and compensated machines has been so marked as to render the old type of machines non-competitive for most purposes.

The old non-commutating-pole machine had no fixed neutral position for the brushes. The generator required that the brushes be moved forward, the motor required that the brushes be moved backward. The amount of brush shift was dependent on the load, consequently, many non-commutating-pole machines cannot be satisfactorily operated through a wide range of load without changing the brush position. The commutating conditions often depend on the field strength, and many pole tip constructions were devised to assist in producing a suitable magnetic field for commutation. Armatures were designed with wide shallow slots thus reducing the output in other directions, all for the sake of improving the commutation. That is not all, for, with special pole tip construction, the relative strength of armature in the main field was of great importance, if good commutating conditions were to be maintained. This restriction prevented good commutation over either a wide range of load or over a wide range of voltage, and motors could not be made to operate well over a wide range of speed.

In order to meet these inherent characteristics of non-commutating-pole motors and generators, there appeared on the market various well-meaning designs, whereby the neutral zone of commutation was supposed to be more or less fixed. All of this goes to show to what a great extent the designer of direct-current machines has been concerned with commutation, and even with the best type of construction it was impossible to make machines of such ratings as are commonplace today. This is the fact which is of interest to the consumer, for, as has been previously pointed out, the output from a given size armature is proportional to the speed, and with the commutation provided for, the speed has been increased, and the cost and the weight per kw. has been correspondingly reduced.

Reversing motors for large blooming mills, some of which today carry swings of more than 10,000 amps. at 1200 volts would be impossible without special provisions for com-

mutation. High speed generators supplying energy to such reversing motors would not have been considered under the old type of design. The motors for speed variations of 4 to 1, and generators, which will commute throughout the entire range of voltage have widened the field of application of electrical machinery. These are not all the advantages, for, with good inherent commutation, graphite brushes can be used, as a high brush contact resistance is not necessary. Such brushes have a low co-efficient of friction, and they do not wear the commutators as the old carbon brushes did. Both the life of the commutator and the life of the brushes are greatly lengthened.

One of your past Presidents, having under his charge hundreds of mill motors, recently advised the writer that his armature troubles are almost a thing of the past. Hence, it is that operating troubles and maintenance expense have been greatly reduced by improved commutation.

TYPES OF CONSTRUCTION

There are two general types of field construction, which are being used in d-c. machines. One type using commutating poles only and the other type, which is a variation of the commutating pole type and which is called a "compensated machine". The commutating pole machine is made by introducing additional small poles between the main poles. The small poles are magnetized by a winding which is in series with the armature and the brushes are so placed that the coil during commutation comes under the influence of the flux from the commutating poles, which flux is of such value and direction that the cutting of same produces in the coil undergoing commutation, a voltage which neutralizes the voltage of self induction. In a generator, the flux from the commutating pole must be in the same direction as the flux from the main pole immediately ahead and in a motor, the flux from the commutating pole must be in the same direction as the flux from the main pole immediately behind. An easy way of remembering this relation is to consider that in a generator, a piece of the main pole is moved **backward**, instead of the brushes being shifted **forward**, and in a motor, a piece of the main pole is moved **forward**, instead of shifting the brushes **backward**.

This brings the neutral position midway between the main pole pieces, for either a motor or a generator, and by connecting the commutating pole winding in series with the armature, a change from generating load to motor load automatically changes the polarity of the commutating poles.

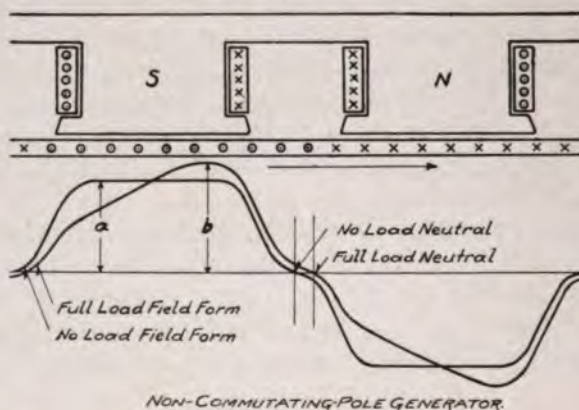


Fig. 1

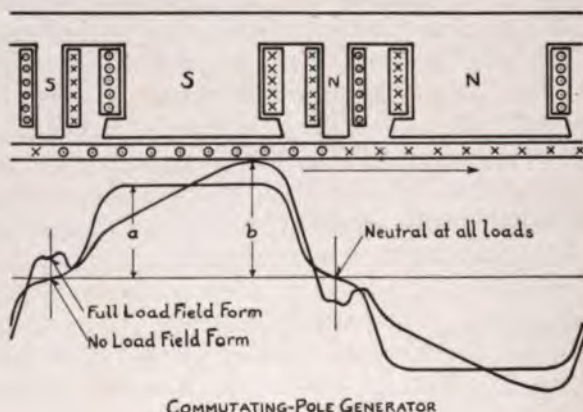


Fig. 2

Thus, such a machine is suitable for either motor or generator operation, without any movement of the brushes. This characteristic is very important and it has opened a wide field of application, which could not be covered by the older type of machines.

The next principal variation from the commutating pole machine, is the compensated machine; in fact, a compensated machine may be looked upon as a modified commutating pole machine. The commutating pole machine has the exciting winding concentrated about the commutating pole, while the compensated machine has a part of the exciting winding distributed in the main pole face. The total excitation is the same in both cases. See illustrations, Figures 1, 2 and 3, of the directions of the currents in the non-commutating pole machine, the commutating pole machine and the compensated machine.

As the commutating pole machine is simpler in mechanical construction than the compensated machine, the

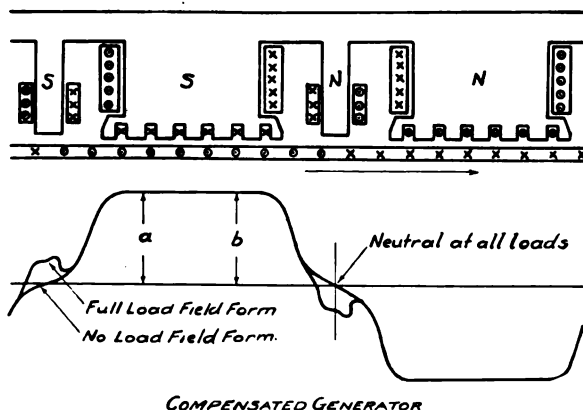
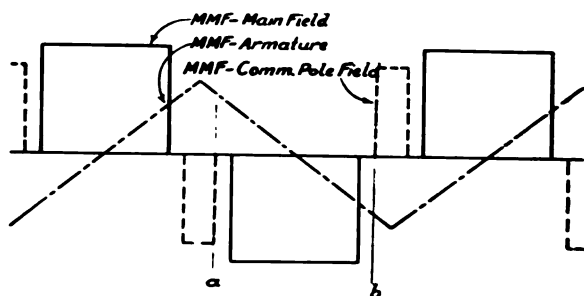


Fig. 3

question naturally arises as to why the latter construction is used. In order to explain this, it is necessary to consider the function of the commutating pole winding. Figures 4 and 5 show the magneto-motive forces, which are present in both type of machines. The essential difference, as will be noticed from an inspection of the diagram, is that in the commutating pole machine, the armature reaction is not neutralized in the zone "a-b", while on the compensated pole machine the armature reaction is completely neutralized under the main pole. In order to maintain the best commutating condition, the flux from the commutating pole must change in exact proportion to the change of load. As soon as there is any saturation in the commutating pole,

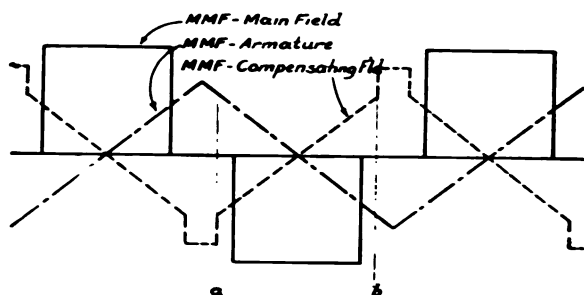
this exact relation is destroyed and the commutation limit is soon reached. It is therefore, undesirable to use shunts around either the commutating pole winding or the compensating winding, as the presence of shunts may destroy the straight line relations between the armature current and the exciting current which produces the commutating flux.

As the commutating pole must carry both the useful flux for commutation and also any leakage flux which may



MMF IN COMMUTATING-POLE GENERATOR

Fig. 4



MMF IN COMPENSATED GENERATOR

Fig. 5

be produced by its winding, it is evident that reducing the leakage flux will increase the commutation limit of the machine. The most effective way of reducing this leakage flux is to distribute the commutating pole exciting field winding in the main pole faces and thereby increase the length of the path of leakage flux. This construction becomes what we have called the compensated machine and it possesses two distinct advantages over the plain commutating pole ma-

chine. It has a greater maximum commutating capacity and as the armature cross-magnetization is neutralized under the main poles, the maximum voltage between adjacent commutator bars is corresponding less. By taking advantage of these points, it becomes possible, by the aid of compensaton, to increase the speed of generators and to make motors which will meet more difficult cycles of operation. Within the limits of the commutating limit, the commutating pole machine commutates just as well as the compensated machine, but the limiting factor in commutation is the saturation of the commutating pole magnetic circuit, and the main factor in saturating this circuit is the leakage flux, and as there is less leakage in this part of the compensated machine, the overload limit is correspondingly increased.

As the number of commutator bars per pole decreases with an increase of speed, a high average voltage between adjacent commutator bars is the result, and if the number of commutator bars is arbitrarily increased in order to obtain low average voltage between bars, the armature reaction is correspondingly increased, and the distortion of the main flux becomes greater, resulting in a high peak voltage between adjacent commutator bars. As has been shown in the compensated machine, there is no distortion of the main pole flux; consequently, with the same degree of safety, a higher average voltage between commutator bars is permissible. That is, with the same peak voltage between commutator bars, the compensated machine can have a higher average voltage between bars than the commutating pole machine. Hence, for very high speeds, the compensated machine makes higher ratings possible. For the same reason, the compensated machine makes higher voltage machines, for a given speed, possible.

The pole face windings and the necessary connections for the same introduce a certain amount of complication, which is inherent to the compensating windings. It is a fact that the compensated machine is not as easily dismantled and not as easily repaired as the commutating pole machine and for pure simplicity of construction and minimum number of parts, we must admit that the old non-commutating-pole machine is superior to either of the later types.

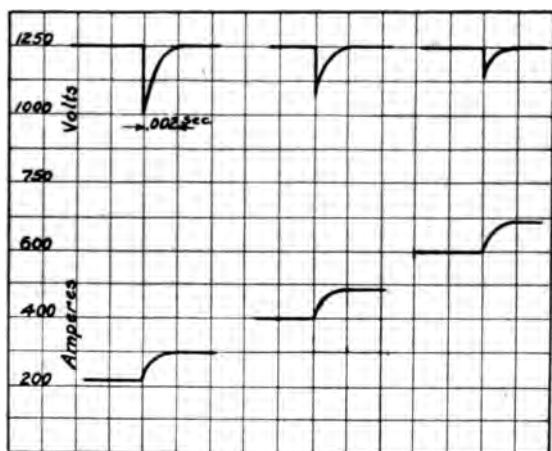
Hence the better performance is obtained at a sacrifice of simplicity and a universal application of compensated machines would be as much of an error as would be an attempt to apply non-commutating-pole machines to all classes of service.

VOLTAGE REGULATION OF GENERATORS

It is generally known that the voltage points, at different loads, on a generator, do not lie in a straight line, but they lie on a curve, the half load voltage being higher than either the no-load or the full load voltage when the compounding is adjusted for the same voltage at both no-load and full load. This characteristic is due to the cross-magnetizing effect of the armature winding and it is present in both non-commutating-pole and commutating-pole machines. The magnitude of this effect depends upon the relative strength of armature to main field and to the degree of saturation in certain parts of the magnetic circuit. The chief difference between the compounding of non-commutating-pole machines and commutating pole machines, is that in the latter type, less series turns are required to give a certain compounding, because in a commutating pole machine the brushes are placed in the neutral position and there is no **demagnetizing** effect from the armature. In practice, the series coils of a commutating pole machine will have less resistance than the series coils of a corresponding non-commutating-pole machine, and to parallel two such machines, it is often necessary to connect a resistance in series with the series winding of the commutating pole machine. The compensated generator has a straight-line voltage regulation. This is because the cross-magnetizing effect of the armature is neutralized by the pole face winding. No trouble, however, is experienced in operating all three types in parallel. For parallel connections of commutating pole or compensated machines, the commutating pole winding and the compensating winding are treated as a part of the armature circuit, that is, the equalizer is brought out where the inside end of the series winding connects to the outside end of the commutating pole or compensating winding.

The question of generator voltage regulation is often confused with the change in voltage, which occurs with a

sudden change of load. The two characteristics are entirely different and no attempt should ever be made to apply the same limitations to them. Voltage regulation, as generally referred to, applies to a change in voltage due to a gradual change of load, as distinguished from an instantaneous change of load, the voltage being read by an ordinary voltmeter. Such change of load extends over a period of at least a few seconds and is of sufficient time to permit of a settling of the voltage, representing the usual condition of operation. In certain classes of service, the load changes very suddenly



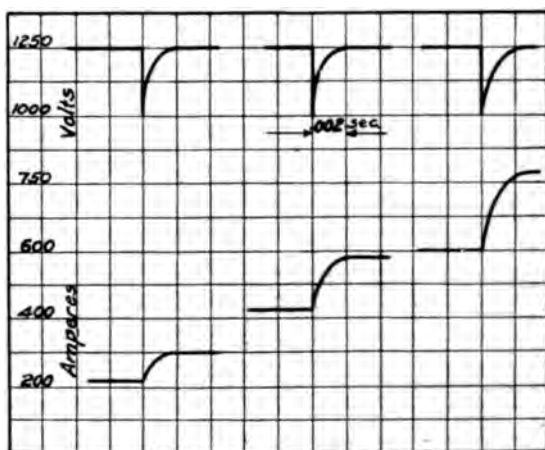
Variation in Voltage, Due to a Sudden Increase of 80 Amperes Load on a 500-KW, 1200-Volt, 900-R.P.M. D.C. Generator.

Fig. 6

over a very wide range. These changes, if momentary, produce variations in voltage which are of very short duration, but of large magnitude. For example, suddenly throwing full load on a generator may reduce its voltage to almost zero and suddenly throwing off full load may increase the voltage twenty-five per cent. These changes, which are of very short duration, can only be measured by an oscillograph and except for circuits used for lighting, these changes are of no consequence. All types of d-c. generators show these momentary changes of voltages with instantaneous changes of load. See Figures 6 and 7.

EFFICIENCY

In efficiency there has been no particular gain made in changing from the non-commutating-pole construction, in



Variation in Voltage, Due to a Sudden Increase of 38 Percent Load on a 500-KW, 1200-Volt, 900 R.P.M. D.C. Generator.

Fig. 7

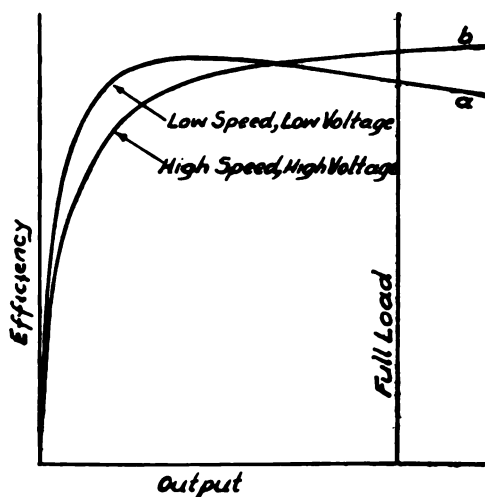


Fig. 8

fact, it is evident that the introduction of additional windings has occasioned additional losses. To counteract this

effect, which would in itself have meant a reduction in efficiency, it can be said that less total losses in the main field are necessary and one very important fact in this connection is that with a special means of taking care of commutation, deeper slots are permissible and consequently a more liberal section of armature copper can be used, thus reducing the losses. As the maximum point on an efficiency curve is where the variable losses are equal to the constant losses, it might be noted that in either low voltage or low speed ma-

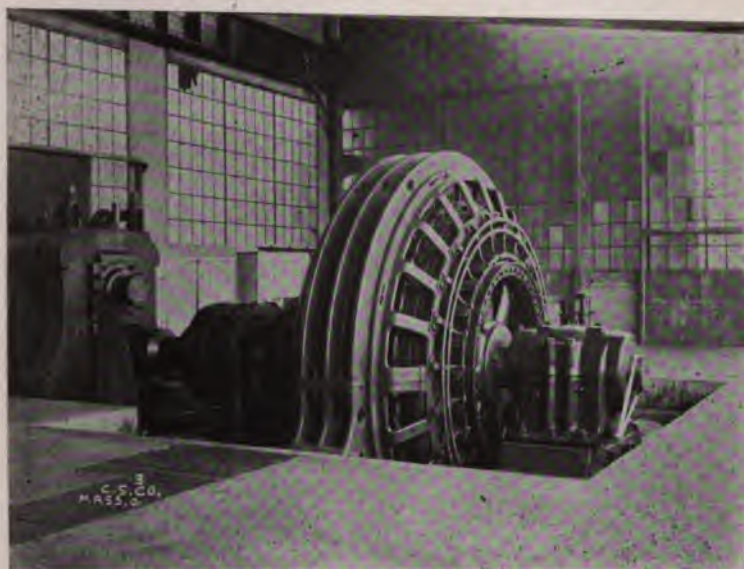


Fig .9

chines, the constant losses are generally low as compared to the variable losses and the curve takes a shape like "a" Figure 8, in which the maximum point on the efficiency curve occurs at less than full load. In high voltage, or high speed machines, the constant losses are generally higher, as compared to the variable losses and the efficiency curve takes a shape like "b", Figure 8, in which the maximum point on the efficiency curve occurs beyond the full load.

Hand in hand with the improvement in commutation, there have been many improvements along other lines, both electrical and mechanical. Armature coils formerly made of wire are made of strap, wherever possible. In many cases,

cotton insulation has been replaced by mica, and asbestos. Cast steel and rolled steel have taken the place of cast iron, thus improving the magnetic quality, increasing the strength, reducing the weight and the size. Better brushes are contributing to long life of commutators, and better commutation has made possible the use of softer grades of brushes, brushes which contain graphite, and which have no abrasive quality, and which possess the desirable quality of a low friction coefficient.

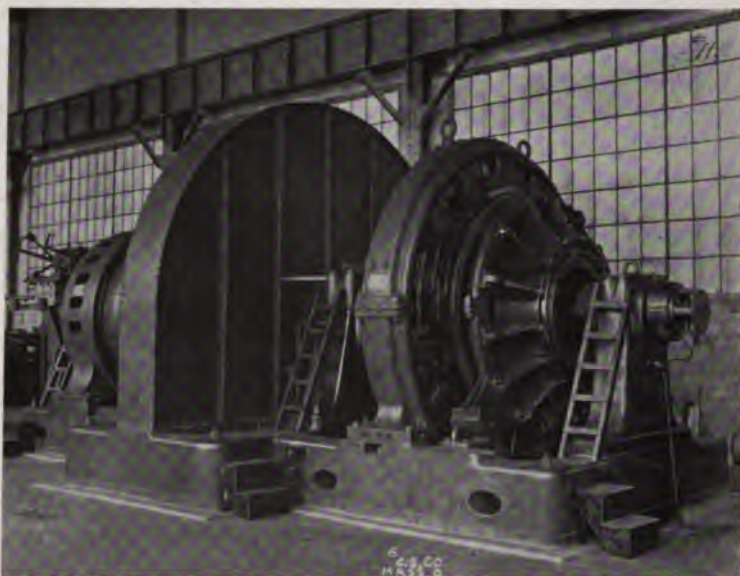


Fig. 10

There have been designed various lines of direct current machines, embodying special means such as described for insuring good commutation. Some of these lines have been made especially for steel mill application, such as the steel-mill motor.

Figure 9 is a typical compensated motor for a reversing blooming mill. Such motors have a special rotor construction, which is made to withstand shocks, such as are characteristic to this application; the armature windings are braced at both ends outside of the armature core, and all

parts are more rugged than is necessary for ordinary classes of service.

Figure 10 is a flywheel motor generator set, which supplies energy to the motor shown in Figure 9. The direct-current generator is compensated and it is capable of supplying momentary loads of three times its normal heating load.

Altogether, the direct-current machine has been greatly improved by the introduction of special means of securing good commutation. Its field of application and its flexibility have been greatly widened, and at the same time the cost and the weights have been materially reduced.

As an exceptional illustration of the satisfactory service of modern motors, the writer has in mind a particular rolling mill where some 175 motors, aggregating 5000 h.p., are in use, and in the last two and a half years the only repairs necessary to these 175 motors has been the re-winding of two armatures.

DISCUSSION AT CHICAGO

W. T. Snyder: This paper will now be thrown open to discussion. In view of the extra attachments that the motor designers are continually tacking on to our direct-current motors, I wonder if it is not in a way putting the steel mill fellow in the position of being scared at the cars. It would appear that the ideal motor would be a simple revolving piece of iron for an armature, without any winding, and a magnetic hoop around it, without any winding, but the longer the designers work on these matters it seems the further they get away from that ideal. At first we had a motor with four poles and it seemed to operate satisfactorily. Then they tacked four more poles on it, and in some cases it had to be done. Then they came along with another set of compensating windings.

We certainly had motors that were designed and built over ten years ago, with four poles that gave ideal commutation under certain conditions. We have also had motors that were built very recently, with the additional set of commutating poles that did not operate satisfactorily. The ad-

ditional set of poles were removed and an improvement was noticed.

Chas. Fair: In reference to Mr. Hall's paper on the advantages of modern types of direct current machines, his clear, concise treatise of the three types of machines is very much to the point.

He does not, however, in his conclusions, indicate to the reader what motor services can be best handled by the compensated type of machine. He also treats the subject as though the motor were the only apparatus to be considered in the installation. There is one class of motors which has been the bug-bear of designing engineers for years, that is, adjustable speed motors with three or four or even more to one speed ranges with reversing, running at different speeds and loads, with pump back, dynamic break, acceleration by field weakening. In the past this has been accomplished by complicated control mechanism in order to favor the motor, usually at the expense of cutting down the cycle, which it was desired to obtain; the motor being the limiting feature, giving commutating troubles, which necessitates the re-finishing of commutators altogether too often. This same thing sometimes happens to commutating-pole motors when equipped with drum controllers for machine tool service on a great many tools, unless the operators are especially instructed in operating the controller.

No one connected with the electrical industry likes to see the limiting feature on an equipment the electrical part, but such is too often the case, unless excessive repairs to the motor or complications to control is provided. For just such conditions as these the distributed-wound adjustable-speed motor, is not only justified but when considered as a unit with its control, is very much simpler than the commutating-pole type.

One may possibly be led to believe, from studying this paper, that the distributed-wound motor is very much more complicated than the commutating-pole motor. It possibly is, when the number of connections are considered, but connections are the least of the designer's troubles and usually the last thing to give the operator trouble. A fully compensated machine has fewer armature coils and correspondingly fewer commutator segments to insulate, with its at-

tendant advantages of thicker commutation bars for a given diameter, and the compensated fields themselves are smaller and of fewer turns, since there is less armature reaction to compensate for. Also the even voltage distribution and the commutator on severe peak loads. The absence of this is one of the principal causes of sparking in commutating and non-commutating pole machines.

On duty cycle machinery where the motor is reversed by the action of the machine itself, with a gear or direct-connected installation, it is obvious that the breaking and reversing must occur on the same segments of the commutator, hence after continual use, which may be only a few days, the commutators begin to show signs of stress on certain segments. This deterioration is detrimental to the machine and unless periodically corrected will make the machine inoperative.

The smallest visible pin sparking and even invisible sparking sometimes due to high voltage between segments which several years ago would have been called perfect commutation, is now no longer tolerable for this class of work. The correct solution therefore, appears when considering the control and motor as a unit for this class of work to be the fully compensated machine with its simpler controlling mechanism.

Operators of direct current machinery accept commutators and brush rigging as a necessary evil. Ask the man in the shop how he likes the certain direct-current motor which he may be operating. He does not tell you he thinks there are too many coils in the motor or that the motor runs cool or too hot, but usually he says that outside of the sanding in the commutator occasionally, the motor is a good one. Therefore, anything that can be done in the design of the motor to further eliminate commutation troubles and at the same time simplify controlling appliances or make the motor stand more punishment with the same controlling appliances, is to the advantage of the user, and by re-arrangement of the coils in the commutating motor, the compensating motor is derived and in time will probably be the universal motor for this class of service.

In the last paragraph of Mr. Hall's paper, he states that in a particular rolling mill are 175 motors aggregating

5000 h.p., the repairs necessary to which having been only the rewinding of two armatures in the past $2\frac{1}{2}$ years. This would seem to indicate that practically no trouble is being experienced from field windings, and hence the introduction of a compensating winding, in addition to the commutating pole winding, which will greatly improve operation, should be very desirable.

Jas. R. Downs: Mr. Hall is to be congratulated on his very excellent paper. It is remarkable that he has been able to so thoroughly cover the important steps in the design of d-c. machines, up to and including the interpole compensated type machine, in so short an article.

It is a fact that most of the early types of direct current machines had very definite commutating limitations, and as Mr. Hall points out, many and varied were the attempts made to overcome this, the greatest obstacle in direct current machine design.

The author mentions that interpoles were known for several years before their general use, and it is also true that the use of compensating windings in the pole faces, were understood, electrically speaking, a good many years ago, as machines so equipped were put in service in 1904.

It has, however, remained for conditions as they exist at present, with the higher temperature limits permitted, with the greater range in voltage required, with wider range in speed variation, with the handling of heavy swinging loads, with the sudden changes in the direction of rotation, etc., to call for the combining of the interpole, and the compensating winding in one machine.

And this means a greater kw. output for a given amount of material, less brush trouble and a longer life for the commutator, and in fact, for the whole machine, with a consequent reduction in the number of repair parts required, and a lowering in the cost of maintenance.

There are many problems to be solved in steel mill application, both electrically and mechanically, and it requires careful co-operation between the steel mill engineer and the motor manufacturer if the best results are to be secured. Where it is at all possible, the definite cycle of operation to be performed should be known in advance, also the character of the material to be rolled, in the case of rolling mill work,

as this has a very definite bearing on the details of the motor design.

There are some applications where quick acting fields are required and there are other applications, where on account of the work being done and the nature of the control equipment used, it is desirable to use, relatively speaking, slow acting fields, and this is accomplished either by using solid pole pieces with laminated faces or with some form of dampening device.

There are some applications where a normal starting torque is all that is necessary, but if conditions should come about to demand a heavy starting torque, the interpole compensated type of motor has the advantage that its maximum commutating capacity is at rest.

Improvements in details of construction have been many and include such features as the sectional wound ventilated shunt field coils, compressed wooden wedges for holding the armature coils in the slots, and ventilating pieces riveted to the laminations to prevent crystalization and breakage.

The use of the multi disc oiling system is also an improvement over the solid oil ring.

The method of applying a motor to a given class of service requires careful study, that is, whether it is a belted proposition, a direct-connected proposition, or a geared drive, and if a gear drive, whether it is to be a spur gear or a helical gear, and further, whether it is to be a two bearing or a three bearing motor. Some motors operating at very high speeds are for direct connection only.

Still there are other drives that have their own peculiarities, such as the vertical motor belted to a vertical mill, requiring a certain tilting of the motor, also a certain relation between the center lines of the driving and driven pulleys, depending on the belt centers used.

So many and varied are the drives and conditions met in your service, that it is exceedingly difficult to say where the steel mill drives begin and end.

The wide range of direct current motor application today, with its consequent lowering of the cost of production, and in many cases improvement in the quality of material produced, is due to the advantages of modern types of direct-current machines.

G. E. Stoltz: The different features outlined by Mr. Hall in his paper are simply items which take care of some fundamental defects or characteristics of the direct-current motor. The question of commutating poles or compensated windings are simple features which allow us to work our material to a greater extent, and thereby manufacture a more economical motor. The present trend of prices, over the last ten or fifteen years, would lead one to expect that the price of electrical apparatus should increase, while as a matter of fact a man can buy a 10 or 100 h.p. motor cheaper today than he could several years ago. If we were to manufacture a motor as described by the president, I don't believe any one would be able to dispose of it.

S. C. Coey: I think Mr. Hall is suffering under a misapprehension to a considerable extent in making the statement that he thought that most of the members of this Association were not very much interested in direct-current machines any more, for I am inclined to think that at the present time more thought and attention is being put on direct-current machines than perhaps any other one feature of electrical engineering in the iron and steel business.

Mr. Hall has presented in a most interesting way the various problems entering into the construction of modern types of direct current machines.

As representative of the user I feel that he is right in his assertion that the user is primarily interested in cost and performance. However, I do feel that the cost end of this combination is being given more consideration in many cases than the performance, and especially performance after a few years of operation.

The great majority of drives in a steel plant are pinion driven with the pinion mounted on the armature shaft. I am of the opinion that if we could do away with all the pinions on armature shafts and mount the pinions with separate bearings and then couple to the motor shaft, preferably with flexible couplings, there would be a saving in the upkeep of motors well worth the investment required. However, this is a reform that will come only gradually and in the meantime the motor builders are making a machine to stand up under conditions as they exist. The frame of the machine under these conditions is an important item and

many of the late types of direct current commercial machines have such light frames that they will not stand up under this class of service. This class of service is also very severe on the motor bearing on the pinion end of the motor and when sleeve bearings are used—as they are on many commercial machines—it means that the pinion must be pulled off to change a bearing. There is no question but what it costs more to make a motor with split bearings than sleeve bearings and that sleeve bearings will do as good and perhaps a little better work while they last than split bearings. The point is only appreciated when a bearing has to be changed with a mill waiting on it. Then the loss in production is liable to be enough to pay for the increased cost between split bearings and sleeve bearings for all the motors in the mill.

In both motor and generator construction the square wire section looks ideal for many coils. The average repairman believes that square wire coils are the invention of the devil. When a square wire coil has to be raised after a few years of service for any minor repair there is always the liability of bending the wires sufficiently to break down the insulation between turns when it is replaced in the slot. The insulation is more or less brittle and the coil must be forced back in the slot. As this point is not liable to show up in its most serious aspect until three or perhaps six years after the machines are in service the manufacturer is very liable to overlook it in favor of the points in design that make square wire armature or stator coils desirable.

Another point where the manufacturer is liable to go too close to the limit is in working the wire and copper up to the maximum and depending upon the air ducts and forced ventilation to keep the machine cool. This is all right as long as the ducts are entirely free from obstructions, but even with the best of care they will clog to a certain extent and the rating of the machine is automatically reduced. With the present high temperature rise standard this is a serious consideration as cotton is still a factor in most insulation and cotton can not stand over 75°C for any length of time without deterioration.

These are simply a few points that I would like to suggest to the designers and manufacturers of electrical machines from the viewpoint of the user.

A. M. MacCutcheon: Due to the fact that I expected to leave last night, I have not prepared any discussion on the paper, but I greatly appreciate the opportunity offered by my change in plans to hear Mr. Hall present his very interesting and instructive paper. I believe it would be a great advantage in the future to have more papers on such points, bringing out questions of design of material which are interesting to the user, manufacturer and designing engineer.

I have found an increasing tendency of engineers to talk over matters of design, so long as they could consider them no longer concealed secrets of the company. I hope to see more papers, not only before the Association of Iron & Steel Electrical Engineers, but before the American Institute of Electrical Engineers, on the question of design. I might cite the fact that the contribution on the subject of ideal design are very meagre. Mr. Lamme, as far as my information goes, has been the principal contributor on this subject and has written some very interesting articles.

There is one point which has been particularly puzzling to many designers, and that is the question of surging on interpole motors.

I ran across an interesting case of surging that neither myself nor any other designer I have known has been able to explain. Generally we think a machine with a tendency to surge has too strong an interpole. That is a rough way of looking at it. There are other things than the interpole that cause surging, but that is considered to be the primary cause. I weakened the interpole on that machine and it stopped surging, but it then sparked. I made curves of the voltage under the brush, and they indicated that the interpole was too weak. I made the interpole stronger than it was originally and the surging was stopped. We put it to all the tests we could devise, and with the stronger interpole we could not make it surge.

The tremendous overloads which a properly designed interpole motor will carry are astonishing. I have seen a General Electric motor and a Westinghouse motor, each of

the most recent design, in each case carrying 250 per cent. load without the slightest sign of sparking under the brushes, and I would consider it a curiosity worthy of a place in a museum if I could see an old non-interpole machine carrying 250 per cent. load without changing the adjustment and without any sign of sparking. That tremendous overload capacity, without injury to the commutator, is, after all, the strongest argument for the use of interpole machines.

Mr. Coey made the point of eliminating the coupling between the motor and the driven machine. An interesting case was told me by the DeLaval turbine people at Poughkeepsie, where a man had a motor driving a punching and reaming machine. This motor was driving a punch at the time. He had all kinds of commutator trouble until he changed the mounting on the motor and put a belt on 18 in. between center, and the motor operated two years and no commutator troubles were apparent during that time. I thought it an interesting case of how vibration, a mechanical difficulty, causes poor commutation.

Looking into the future, and considering the possibilities which the future may hold, but which we cannot at present see, I believe that the ideal motor will have no interpoles, no compensated windings, but according to the laws of making the best use of nature's law of conservation of energy, some one will devise an armature winding which corrects itself, and then you have the ideal motor. I might say, further, that I have heard several designing engineers talking on that line, as to whether it is possible or not, and they are by no means ready to admit the impossibility of working out such a motor.

I think from the standpoint of making the best use of your material, it is interesting to note that a machine which is so designed as to be a machine which gets very hot, may be an excellent commutating machine for the same reason that makes it a hot machine. Take a long core machine, with a large quantity of flux. That machine may very well heat up to a point 10 degrees over some other motor it may be compared with, yet that motor may have 50 per cent. greater overload capacity, both on heating and commutation, on heating because there is the big mass of material which produces heat, but that big mass of material has a large

heat storage capacity, and the motor will therefore stand temporary overloads of much greater value for a short time.

W. T. Snyder: We must admit the necessity of interpoles on adjustable-speed motors. Whether that refinement is necessary in all applications is a question in my mind. I can refer to one motor built more than ten years ago, nearer twenty years ago, which gave a great deal of trouble at the commutator; a new set of brushes was required for the motor every few weeks. We finally undercut the commutator and put on good brushes, and the motor ran three years on the same set of brushes and practically no wear on the commutator or brushes, and I doubt whether the commutation could be improved. Had we gotten a new motor at that time, with these improved commutating conditions, and if the motor had at the same time interpoles, accidentally or otherwise, no doubt we would have been strong advocates of interpole motors. I cannot quite see why a motor can not be designed for application similar to centrifugal pumping with constant head and constant output,—at least for the steel mills—without complexity of commutating poles or compensating windings, and still give good commutation.

David M. Petty: In considering the subject of the advantage of the modern type direct-current machine, I think it is well to divide the subject, to a certain extent, between what might be called large special machines and smaller standard machines.

There is one point in the larger sized, as well as the smaller, that I think should be considered, and that is the question of ventilation. The American Institute of Electrical Engineers has increased the Standard for temperature rise in machines to some extent. I do not feel for the sake of reliability that the steel mill people can afford to allow excessive temperature rise. For large drives, I think that the designers could well afford to include as part of the electrical equipment, air cleaning and blowing outfits for ventilation. At the same time, I think the steel mill buyers of electrical machinery should watch the designers very carefully to see that they do not take too much of an advantage of ventilation, and in that way pull down the efficiency.

In a large measure, efficiencies determine the temperature rise of the machine. If a machine is designed for a large amount of ventilation in order to keep cool and a large body of air is admitted to it, and the air is not clean or even what we would call clean in a place like a steel mill, there is always a certain amount of oil vapor carried in the air, which necessarily gets in the windings and carries with it a certain amount of dust and dirt. This dust and dirt stops up the ventilating ducts all through the armature, and it is only a question of time when, if the oil does not cause the windings to ground, the dirt will cause the temperature of the hot spots in the armature to rise to such a degree that it will finally roast the motor out.

I think this question of ventilating ducts through the armature is a very serious one with standard small sized machines. I know particularly of two or three cases where the machines have absolutely roasted out on account of the stoppage of the ventilating duct. I admit that the motor would run cool enough if we could keep these ducts open. That is the point. There are places where they have to be operated where they cannot be kept open. In most of these cases it does not seem that is necessary to go to the totally enclosed motor. An open motor with a liberal rating in which a certain amount of the internal ventilation of the armature is eliminated would probably answer the purpose just as well as a totally enclosed motor.

So far as interpoles and compensated windings are concerned, I think that the designers should be cautioned not to go to too high speeds. I believe it is almost absolutely true that the trouble with commutators and the trouble with bearings and oil rings is almost directly proportional to the speed of the motor. The higher speed motors, if slightly out of balance, will cause a very serious vibration of the brushes, which naturally causes poor commutation, whether the compensating windings are working right or not. The brushes will naturally spark if they are not in continuous contact with the commutator.

As Mr. Hall has said, ninety-five per cent of the direct-current motor troubles is with the commutator, and I believe it can be said also that a large part of the total troubles is due to the brush-holders as much as, if not more than any

other one thing. In my opinion, brush-holders should be so designed that they are easily replaced, not because I think we ought to design brush-holders to be replaced, but due to the fact that it is a small item in the cost. If a brush-holder is slightly damaged and it is hard to replace, the tendency on the part of the operator is to keep the motor going with a poor brush-holder, and it is only a question of time under those conditions until the armature or the commutator, or some other part of the motor vastly more costly than the brush-holder itself, is worn out, or put out of commission.

I think the designers of direct-current motors, after they have gotten through with compensating windings and interpoles, should give very serious thought to brush-holder design. With the brushes themselves, it seems to be largely a matter of how much money you want to spend for brushes.

I agree with a number of the electrical engineers that interpoles are not necessary on a good many types of machines, and my experience is that they are not even desirable in some cases. I refer particularly to series-wound motors used on cranes, etc. If the interpole is not necessary it is not desirable as it then causes extra connections.

R. B. Treat: The paper touches lightly on the subject of change of voltage occurring with a sudden change of load. This "flicker" in the voltage disturbs no one whose load is all motors, and did not disturb anyone while the carbon filament incandescent lamps were in vogue. With the advent of the tungsten filament lamp, any voltage flicker became noticeable.

At present many power plant operators, having only a light load at night, are giving serious thought to the lamp flicker, if a frequently starting motor is on the circuit. Even in the daytime, with larger generators running, this flicker occurs with annoying frequency in office buildings having many electrical elevators. Each start of an elevator may be noted by the lamp flicker.

It is reasonable to expect that the modern commutating pole generator will permit a more noticeable flicker than will one of the older type of non-commutating-pole machines.

a combined interpole and series turns offer more
 as opposition to a small change of current, than

do the series coils alone of the old type machine. The armature of the modern machine has a greater number of turns per circuit than had the older machine, which again aggravates the flicker.

The subject of efficiency of the modern machine over the old type has not received much attention, because it has been left in the back-ground by the manufacturers, while the consumers attention was concentrated upon commutation and ventilation.

The general effect of interpoles on the no-load losses is to decrease them, for a given size machine. The brush friction losses are less. The armature core iron loss is less, because less total flux is used, and consequently less weight of iron. The shunt field excitation is less because of shorter air gaps.

The highest point on the efficiency curve occurs where the no-load losses equal the load losses, and because of the lower no-load losses, the highest efficiency point is at a lower load.

The load losses plus the no-load losses are made just as high as the designers skill in juggling ventilation to meet specified temperatures will permit.

We may take the author's curves, Figure 8, curves "a" and "b" as fairly well representing the efficiency curves of the new and old machines. Curve "a" is that of the new interpole design, and curve "b" that of the old non-commutating-pole design of the same output, voltage and speed.

Curve "a" is typical of the modern design which is made up of commutating-pole plus "single rating" (extreme ventilation with no over load capacity).

Curve "b" is typical of the non-commutating-pole machine plus heavy cross sections of copper, because of less attention to ventilation.

The question of generator efficiency will again have its day, and we may arrive at the conclusion that when $\frac{3}{4}$ -load is reached, it is most economical to throw on another generating unit, instead of the old common practice of saving steam by running the old machine at $1\frac{1}{4}$ -load.

David B. Rushmore: I have not prepared anything on this subject, but have spent a good many years in de-

signing machines; it is very interesting to see the improvement in designs and to see how the use of material has been raised in efficiency. There is a natural limit being approached where copper and iron, at certain velocities, are not going to be able to continue to develop greater output. The limitations of design and operation, especially for variable and adjustable speed motors, are constantly changing back and forth, either the manner of heating or manner of commutation, and designing engineers have always been working to meet and overcome the thing which was limiting their output. The reason for this is on account of you gentlemen and the concerns you are associated with insisting on a continual lowering in price. Many of the motors which were built fifteen or twenty years ago are running with entire satisfaction up to their rated capacities, but the weight per unit of output to the price was much greater than at the present time.

It is interesting to see what room still exists for improvement, and there is one gentleman in the room who should be very much concerned with this part of the field, and that is Mr. Martindale of the National Carbon Company, because with him and his company lies one of the things in improving conditions that has not been entirely exhausted, although they have doubtless made very strenuous efforts to do so. The design of carbon brushes still holds out possibilities for improvements.

Naturally, the mechanical adjustment of these brushes is a very great feature of satisfactory or unsatisfactory operation, but I would like to speak of two points which have recently been brought to my attention, both of which have a very intimate connection with Mr. Hall's very excellent and very interesting presentation of the subject.

An engineer from abroad, who was recently in attendance at a meeting of this kind, said he was astonished at the relation which existed in this country between the operating companies, the purchasers of apparatus, and the manufacturers. He said that in England nothing of the kind is found to exist. He stated that the manufacturers are always trying to put something over on the operating people, and the operating people are always trying to prevent something being put over on them.

He further said that the very close connection and mutual good understanding and co-operation towards the working out of difficulties and problems that existed in this country excited his very sincere admiration. It is something of which we can all be proud, that such a state of affairs does exist and has been one of the factors in the development of the electrical industry, both in the manufacture and the use of apparatus.

Another quite vital problem will confront us in the future. A Russian gentleman at present in this country, and very closely familiar with the European electrical conditions, was using his utmost efforts to impress on me recently the fact that American manufacturers have got to change their methods, if they hope to meet with any very great success in foreign fields. He said that the extremely liberal margins in American machines was absolutely unnecessary, and from an European engineer's point of view, ridiculous. I do not know how this will sound to an American audience, but those were practically his words. He said that if American manufacturers expected to successfully compete in foreign trade they must sell a motor rated at 25 h.p., which is good for 25 h.p., and not for 26.

George W. Richardson: I might say that I am very much interested in interpole motors. I am like some of the rest of those present—I do not think we need interpoles in all motors and all applications where we put motors. I have recently taken down one motor that has been running three punches. That motor has been running some twenty odd years, and I think the armature, for turning up the commutator, has been taken out twice in that time. The original band on the armature is still on. The original machines were run from a belt. The department wanted us to change, and we decided we would put on the individual motors, replacing the 10 h.p. motor with three 7.5 h.p. motors. The object of using individual interpole motors in this case was desirability of changing speed on each machine separately.

As we wished to speed up the operation a little bit, we started at 24 punches per minute, and crept up to 28, and now the operator is doing very nice work at 28 punches per

minute and is not complaining. We are getting more work out of the punch than we did before.

We have a lot of old motors which have been in use for years, and the trouble is to get rid of them and buy interpole motors.

As to series motors, I do not think we need interpole motors on series work, especially on dynamic braking. I think it would be troublesome. I have one large motor on a machine, and I must say the commutation of that motor is fine. We have pulled the laminations of the machine all apart; twisted them all out, took the machine down, reslotted the keyways, made them larger, after which the motor ran OK. A peculiar thing happened to this machine, which is a 285 ampere one. I designed a cut-out coil to open at 600 amperes, thinking it was ample overload. I had it locked so nobody could interfere with it, and it was not long before the hot bed got stocked up and the mill had to stop. They called me to the phone and said the mill was stopped on account of power. The night superintendent of the mill was there and I said: "You have as much power as you need?" He said: "No". The machine went through with the work that night, and cleaned up the hot bed. Next morning the manager said—"You don't need to bother, it cleaned up the hot bed, and the trouble we had last night was worth that." In the steel mills, if you have to do the work, you must do it.

As I said before, I am much impressed with the paper, and I am also impressed with interpole motors to a certain extent. However, in some places, I do not think I would want to use them.

W. T. Snyder: It would be very nice if we could have the interpole or non-interpole motor, with the parts interchangeable, even though they are rated differently.

T. E. Tynes: In the older days, when we first began to apply motors to steel mill work, the only thing offered was the old railway type, which was woefully unsuited to the work it was put to do. The manufacturers came to our rescue and brought out a mill type motor, and that just seemed to fill the bill. It did the work well, and did it with a minimum of repairs and maintenance and the motor had long life. We apparently were satisfied. Some time after

that they made a discovery that interpoles would add to the commutating ability of these motors, although they were good then. Then they put on interpoles. They also found out that they could decrease the material and they began to do so.

We might put it on this basis: with the old motors we got a pound of engineering, with a pound of service and a pound of material. Through the benefit of the interpole they have given us a couple of pounds of engineering, with the same pound of service, and with a half pound of material, and the end is not yet.

Mr. Rushmore has also spoken of the Russian Engineer and how, if we follow his advice, we will be straining our imagination to get the rating out of the motor. I want to sound a note of warning to designing engineers to please leave us a little material to look at, we like to have something to look at for our money.

James Farrington: There is one point on the question of ventilation. We had a modern motor, small size, having ventilators on the rotor, and due to the sudden stopping the ventilator ring became slightly distorted and changed the direction of ventilation, causing a burn-out in that armature. Therefore, if they are going to ventilate and depend on the ventilator, the ventilating disc should be made mechanically as strong as the armature itself.

C. A. Menk: I have enjoyed the remarks on the modern motor, and it seems to have settled down to the question of interpole motors. A great many manufacturers claim it is unnecessary to install the interpole. Even Mr. MacCutcheon said that the modern motor would be one without interpoles, that the ideal motor would be designed so as to make up for what the interpole is doing now. This seems to be just the right thing for a manufacturer to bring out why they have eliminated the interpole, and what they have done to take the place of the interpole.

E. H. Martindale: Mr. Hall's paper is very interesting, not only from the standpoint from which he wrote it, but also from the fact that it brings out the limitations of future designs.

It speaks very well for the progress of the electrical industry, of which the motor and generator designer is one

of the most important factors, to say that twelve or fifteen years ago he was able to take out a 1000-kw. engine-driven generator, install a 5000-kw. turbo generator, and save space and today that he can take out that 5000-kw. turbo-generator and put in a 25,000-kw. generator in the same space. It appears from Mr. Hall's paper that we have nearly reached the limit of output from a given amount of material.

The question which President Snyder brought up concerning the insistence of motor manufacturers on supplying interpole machines, I think can largely be attributed to the consumer or perhaps more to the purchasing agent. The

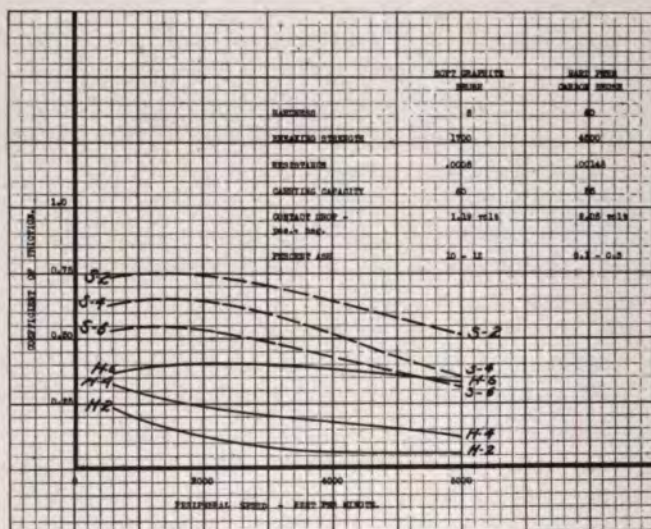


Fig 11

5 h.p. motor built twelve or fifteen years ago would carry 10 h.p. continuously, except for commutation trouble. Today this machine is equipped with an interpole and sold for a 10 h.p. motor. Perhaps these figures are not exact but my point is that keen competition has made it imperative that the manufacturers get the maximum capacity with the minimum quantity of material and one of the great factors toward this end has been the introduction of the interpole.

I believe any motor or generator manufacturer can design a non-interpole machine which will carry as much load as an interpole machine if the service can be accurately pre-

determined and will always remain the same steady load. With a non-interpole machine designed for its maximum capacity any underload has almost as serious an effect on heating and commutation as an overload.

The particular point I wish to discuss in Mr. Hall's paper is the statement as follows: "Better brushes are contributing to long life of commutators and better commutation has made possible the use of softer grades of brushes, brushes which contain graphite, and which have no abrasive quality, and which possess the desirable quality of a low friction coefficient." I want to make emphatic the statement that it is not necessary to have graphite in a brush to get low coefficient of friction and non-abrasive qualities. Fig. 11 shows the characteristics and coefficient of friction curves for one of the softest and one of the hardest brushes manufactured. The curves marked S-2, S-4 and S-6 are coefficients of friction of the soft brush at 2, 4 and 6 lbs. respectively and similarly the curves marked H-2, H-4 and H-6 are the coefficients of friction of the hard brush at 2, 4 and 6 lbs. per square inch. The abrasive qualities of a brush are dependent on the percentage and composition of the ash. Ash in carbon brushes is generally composed of mica, silica, quartz or iron oxide. The percentage of ash in the soft graphite brush is 10% to 12%, while in the hard carbon brush it is from .1 to .3 of one per cent. It is interesting to note that the friction of the soft graphite brush decreases with increased pressure while the reverse is true of the hard carbon brush. This is probably due to a greater mechanical wear on the soft graphite brush which results in a graphitic lubrication of the ring, while in the hard carbon brush no such mechanical wear occurs. This rapid mechanical wear of the soft graphite brush naturally means a short life and for that reason we recommend the use of a hard pure carbon brush for high speed undercut commutators.

Mr. Rushmore, in his discussion of Mr. Hall's paper brought up the question of improvements in brushes. We are often accused of having been asleep on brush improvements until an importer woke us up about ten years ago, but the fact of the matter is that it required the importer to wake up the consumer. Before imported brushes were

heard of in this country we had a brush we called the "New Departure Brush," but we made extremely slow progress in getting it introduced. In those days it was a rare thing for a salesman to talk to an electrician and when he would go to the purchasing agent with his story about the "New Departure Brush" the first question would be, "How much does this 'New Departure Brush' Cost?" The answer, "Three times the cost of the other," generally resulted in expletives and an invitation to "get out." When, however, someone came along with a brush made in another country the purchasing agent thought it must be better.

As we had been unable to develop our own carbon brushes we were not prepared to meet the competition and it took several years to get under way. Since Mr. Rushmore spoke of the improvements in brushes I have counted up the results of development and find in the last eight or ten years we have developed thirty-two new grades. Eleven of these have been thrown into the discard. Seven new grades have been brought out in the last two years.

I believe most of the domestic manufacturers have brushes which will operate just as satisfactorily and more economically than the imported brushes. We are not willing to admit that European methods or European brains are better than American. The American manufacturers are all awake and large laboratories are endeavoring to develop brushes which will enable the manufacturers of motors and generators to get up to their limits of mechanical speed.

I can assure Mr. Rushmore that the end of the development has not been reached.

R. H. McLain: As to the matter of putting on interpoles and compensating fields, two features have been brought out. One is to reduce the material and consequently cost, and the other is to enable the motor to do performances it otherwise could not do.

Some of the gentlemen who have discussed the subject have gone back to machines that were manufactured ten years ago, and just to make the thing a little more apparent, I will go back twenty-five years. One of my first jobs was tending to a machine which is now twenty-five years old my job at the time was to shift the brushes on

the machine to keep up with the variation in load. It is apparent that the trouble with this machine was that it did not have commutating poles and several other improvements. Another thing about the machine was that it was considerably taller than I am, although only 2,000 kilowatts capacity. What would we do with that kind of a machine on a crane, for instance, without an increase of head room in all of the buildings?

I am merely mentioning this old machine to show that when we get these new motors we should appreciate them.

When it comes to the particular features discussed in the paper, I would like to call attention to the fact that it is not in the moving parts of the machine, or control, where the so-called complications are being introduced. It is in the stationary parts, that is, in the fields. The performance is being made simpler, and the present complications of the armature could be made simpler, if desired. Also, the control apparatus is made far simpler.

A thing that can be done now that was unheard of years ago is to take a 550-volt adjustable-speed machine wound for 300 and 1200 rev. per min., let it run at 300 rev. per min., weaken the field in one jump, have it jump up to 1200 rev. per min., and then strengthen the field in one jump and have it jump back to 300 rev. per min., without any distress.

These new field windings permit such things as above described. They have other needed advantages. Certainly, they do not have to be used in absolutely all places. I do not think the compensating winding is at all necessary except in the larger sizes, or where very complicated things are to be performed.

When it comes to crane service, or coal and ore bridges, everything that you can do to cut down in the weight is certainly an advantage in performance as well as in cost. When we say cut down in the weight, it does not mean that you should cut down in the weight just to take out cost; you can cut down in the weight where the weight is useless and add it to the shafts and bearings where the weight is needed, and that is an improvement, even though you keep the same total weight of machine.

Mr. Petty mentioned the matter of using interpole motors for dynamic braking on cranes, and I would like to testify on the other side of the case. All of the cases I have noted show that an interpole machine could obtain higher lowering speeds on dynamic braking than the machine without interpoles. It is true, that if the interpoles were not put in with the idea in view of having the machine perform this way, they might not do so. However, it is no more expensive or complicated to put them in so that they will perform at high speeds than otherwise. I think sufficient proof is that you can get an adjustable speed shunt-wound motor 2 or 3 to 1 by means of commutating poles, whereas, you cannot get it without commutating poles. To run a crane hook down on dynamic braking, with a series-wound interpole motor, is nothing more nor less than to make an adjustable-speed shunt-wound motor out of the series motor.

To get down to a specific case, I have made tests of machines which were exactly alike, except for interpoles, and could get with the same character of performance at 50 or more per cent. higher speed on lowering with the interpole motor than with the non-interpole motor.

W. T. Snyder: As to Mr. McLain's difference of sizes, I can go back four months and refer to one motor that overhung the face plate of a lathe by 12 inches and we replaced it with another motor of the same operating characteristics, made by another firm, that cleared the face plate several inches.

G. E. Stoltz: We took two motors, the difference between them being negligible, except one was a commutating and one a non-commutating pole motor, coupled the two together, and used them alternately as motors and generators, loading one for fifteen minutes and then reversing the operation by putting the load on the other. The one which happened to be acting as the motor was started and stopped every 13 seconds, this service being continued day and night until the operation of one or the other was unsatisfactory. Starting on comparatively light load, only a slight difference could be noticed in performance of commutating pole and non-commutating pole motors. After this operation was carried on for several days the load was increased. The test

was run at various loads, and as the loads were increased the difference between the performance of the two motors was greater. The non-commutating pole motor could not withstand the loads and heavy reversing service that the commutating pole machine could stand, although on light load, when the service was not so severe the difference was not so noticeable.

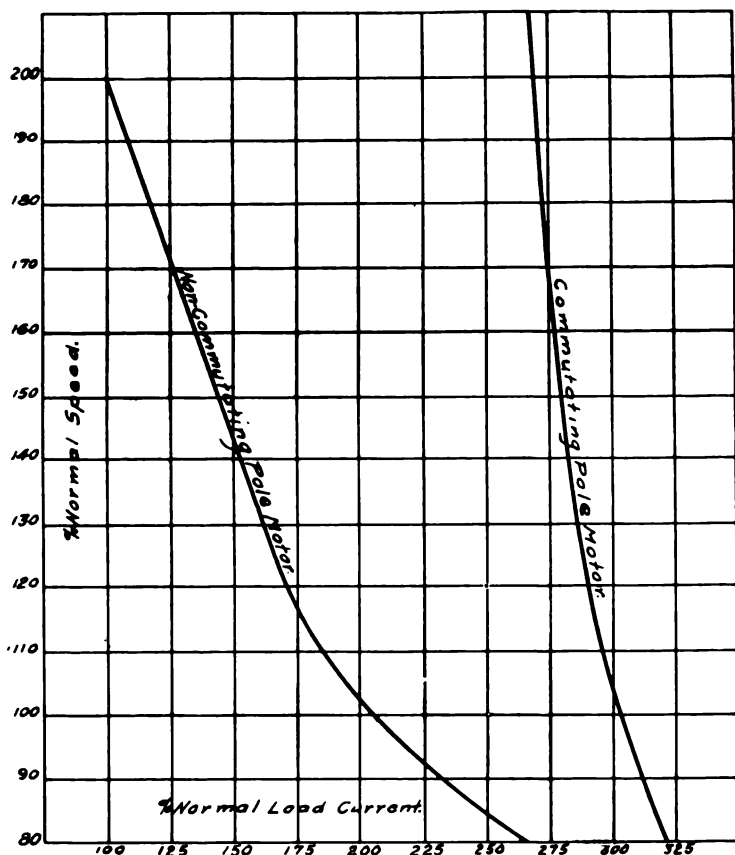


Fig. 12

The curve shown in Fig. 12 was obtained by plugging the motor and suddenly reversing its direction of rotation. The object of the test was to obtain the maximum plugging current permissible at the various speeds. The values which this curve represent were taken when a slight spitting

was produced on the commutator. At 50% above normal speed the non-commutating pole motor is able to commute 45% overload, while the commutating pole motor, under the same conditions commutates 180% overload.

This brings out the fact that a commutating pole machine has greater capacity for overloads and will withstand severe service easier than the non-commutating pole machine. The machines were paired off with the idea of having two machines of practically the same weight.

D. M. Petty: Which showed up the better?

G. E. Stoltz: The commutating pole machine showed up better as the load was increased. The result of all sizes we tested, the non-commutating pole machine would show a blackened commutator quicker than the commutating pole. That was the more noticeable as the service was more severe.

D. M. Petty: I believe in interpole motors, but I also want to be sure to get the facts correct. Were these motors of the same weight, and in one case the motor designed as a non-interpole motor and in the second case motor designed as an interpole motor, or were both motors designed as interpole motors, and you left out the interpole in one of them, or both motors designed without interpoles, and you put in an interpole in one of them?

G. E. Stoltz: One was designed as a commutating pole machine and the other as a non-commutating pole machine, and both sold as such.

C. T. Henderson: A very minor modification of the mill type motors, which often produces beneficial results, does not seem to be mentioned here. In my experience I have found in several cases the use of damping grids, such as are ordinarily employed on rotary converters, will produce very desirable results when applied to the mill type motor, operating under varying load conditions, especially where the load fluctuates very rapidly and a considerable amount of control is to be accomplished. It seems to have the effect of damping, to a slight extent, the current, and improving the general operation of the entire system.

David Hall: Were they connected?

C. T. Henderson: The pole faces were slotted and the grids simply inserted in the pole faces, so as to provide a path for generating currents in these grids.

David Hall: I agree in general with the comments which have been made. I believe that the iron and steel electrical engineers are more interested in direct-current machines than I first thought. I feel, in view of some of the remarks, that there will be a good many mistakes made along the line of these commutating pole and compensated machines, and I hope you will take this paper in the spirit in which it was written. The paper was written with the idea of giving to those who would read it carefully a more comprehensive idea of the performance of commutating poles and the purpose of compensated windings and to show wherein these modifications make certain machines possible.

The President seems to have the feeling that many of the old machines are good enough, and they have no commutating poles and why introduce complications? I would like to make a few remarks along that line.

Some twelve years ago I had the pleasure of assisting in the design of a machine which is still in operation in Cincinnati, rated at 3,000 kw., 275 volts, and runs at about 75 rev. per min. That machine I think is the largest rotating diameter direct-current machine in the world. The armature is 270-in. in diameter.

I will call attention to a machine in Cleveland of 3750 kw., an increased output of 25 per cent. and the speed is 180 rev. per min., instead of 75. That machine has an armature diameter of 180-in. We can build machines today of 3,000 to 3500 kw. capacity to run at a speed of 300 rev. per min. The armature diameter would be approximately 100-in.

Now, whether you want a machine, or do not want a machine, with commutating poles or compensated windings, is not the point, when you ask for a 3,000 kw. machine to run at 300 rev. per min. The point is, how should the machine be designed so that it will give 3,000 kw. at 300 rev., and the only way to design it is by introducing either compensating poles or compensated windings, or both. The old type of machine must fade away. You cannot consider the building of such a machine. You cannot build a ma-

chine of anywhere near 3,000 kw. at 300 rev. per min. without introducing some external means whereby commutation can be taken care of.

There have been a number of remarks about the misapplication of commutating poles. That will probably be a subject that we will have with us for a good many years to come, because there are lots of non-commutating pole machines today which are not performing as well as modern commutating pole machines, and the users will be inclined to put commutating poles into the machines in some instances in order to get good commutation.

This paper has pointed out a few fundamental elements necessary for satisfactory operation of commutating pole machines. In the first place, you must have more excitation on the commutating pole than on the armature, probably thirty per cent. That is a rough figure. I have seen machines run with ten per cent. excess, and other machines with 40 per cent. excess, but there must be in every case some excess of commutating pole ampere turns over the armature ampere turns and when any machine is built with 85 per cent., that is not a condemnation of the commutating pole. It is a condemnation of the designer who put in the commutating pole.

No one should introduce commutating poles and expect satisfactory results unless he knows how to design them. If we put in the right kind of poles, we will have better commutation. All non-commutating pole machines are not suitable to having commutating poles put in them.

Perhaps I might press home a point here, that many of the old armature windings were chorded as much as two slots—for example with fifteen slots per pole, winding 1 to 14 was chording two slots. Such windings require a wide commutating zone. In fact the commutating zone in some old machines is almost as wide as the distance between the main pole tips and you could not introduce a suitable commutating pole, but we must not condemn the commutating pole because it will not take care of an old machine which was never designed to have a commutating pole.

I will not attempt to follow in detail the various points which have been made, because I agree with most of them.

The use of gearing was referred to by Mr. Coey, and

I will say, (with reference to his point of trying to abandon gearing,) that troubles have been caused by introducing gears between the armature shaft and the fly-wheel shaft.

For instance, if we have a motor geared to a counter shaft, and on the counter shaft we have a fly-wheel, and from that shaft we gear into a roll, thus introducing a fly-wheel between the motor and the rolls, we get a very bad hammer effect from the fly-wheel, because it is on a different shaft from the armature. I feel that there have been misapplications along that line which have given trouble. Armatures have broken down because they were being hammered by a fly-wheel, which no armature could withstand.

I have always been opposed to the use of square wire in general and have used it as little as possible, because I always thought it was a thorn in the flesh in many ways. However, the square wire does have its advantages in section over the round wire, and in some places it is valuable and justifiable. The square wire in field coils, I think is justifiable, because it eliminates, to a certain extent, the air space. A field coil wound with square wire versus a field coil wound with round wire, has less air pockets or spaces to be filled up with gum or something of that nature, and it conducts the heat better, giving a coil of more uniform temperatures.

There is some economy in using square wire in certain field coils. The square wire coil of a given number of ampere turns can be put in a smaller space than a round wire coil of the same number of ampere turns. That is the fundamental advantage of it.

The surging of machines or the unstable speed at different loads is a subject which could well occupy an entire meeting.

We had surging in the old non-commutating pole machine for the same reason we have it, to a certain extent, in the commutating pole machine. It is due to the demagnetizing and cross-magnetizing effect of the armature ampere turns.

There is one possible way of slightly improving the surging condition in commutating pole machines, if the com-

mutation will permit the shifting of the brushes, a slight shift forward will give a stabilizing action.

So far as producing a new and simplified machine is concerned, personally I do not yet see the dim light in the future which will eliminate the present factors. I do not feel very hopeful along that line at the present time.

In regard to the air cleaning, which Mr. Petty commented upon, I believe that is a subject which is of great interest on large equipments, the continuous operation of which is very important, and which represent a very large investment. These large reversing rolling mill equipments, such as Mr. Petty has under his charge, demand, I think, the care and expense necessary to furnish good clean air. In fact, it seems as though we are almost justified in giving these machines better air than we get.

Now I feel that the designer should take into consideration always the question of efficiency. A machine should be measured on cost and performance. This question of cost has been touched on before by a number of speakers, and, of course, machines are being designed that are much cheaper with the same power than they were in former years. Some years ago at a meeting of the American Institute of Electrical Engineers, I referred to a 30 h.p., 230-volt, 600 rev. per min. with a one-turn coil armature which I knew could commute three times full load, and I said that it was not justifiable to make such a machine with commutating poles. Shortly after, commutating poles were very common and designs were produced which made a cheaper machine, because the number of commutator bars was reduced, two turns per coil being used instead of one turn, and the commutator made of smaller dimensions, and the commutation being taken care of by the introduction of commutating poles. It also commutated three or four times full load. It was a matter of producing a machine for a certain amount of money. A consumer will buy the cheaper machine, provided that he is sure that the performance is equally good.

DISCUSSION AT PITTSBURGH

E. Friedlaender: Our Association should be grateful to Mr. Hall for presenting such an able paper. It is not very often that a manufacturer speaks so openly about the construction and design of his apparatus.

I think the advantages derived from the modern-designed d-c. motor are just as great to the consumer as to the manufacturer. I hope we will not go back to the motor of twenty years ago, when armatures and especially commutators had to be repaired nearly every week, whereas now, the modern mill-type motor will run constantly for years without requiring any repairs except the replacement of bearings.

It is of considerable advantage to us to have weight-per-h.p. decreased, especially on cranes, and at the same time decreased cost-per-h.p.

Much has been said about the additional complication by using commutating fields. I hardly think this is the case. With the fire-resisting material now used on windings, fields are practically indestructible, and if kept clean, should last indefinitely.

Whether the advantages derived from the modern motors are due to better design, better understanding of selecting the motor, better control, or better brushes; this will require some investigation. No doubt much good comes from co-operation between consumer and manufacturer.

L. F. Galbreath: There is no doubt that the commutating pole motor has its field, especially in large machines where there is plenty of room for the commutating pole. The machine gets better care and is better built and has usually a more skilled repairman working on it who is familiar with the commutating poles. On small motors it is a question to me as to whether they have been a success or not, as the commutating poles are crowded. They are placed in the bottom of the case where they are in the oil and dirt and are very seldom clamped to prevent them from vibrating and going to ground.

The commutating poles are lined out with liners which sometimes become lost during repairs and then the com-

mutation is very poor. The ratio of the number of grounds on commutating poles to the main poles in our plant has been about three to one.

W. T. Snyder: Mr. Galbreath brought out a point that has been in my mind right along; I hope the designer will not lose sight of the fact that mill men are often not highly skilled men and are fond of a simple motor, and the tendency seems to be more towards complication. I hope that in their enthusiasm to produce a motor with refined characteristics that they will not add too many complications.

C. F. Lloyd: In reading Mr. Hall's paper, the point that impressed me mostly, was the fact that he dwelled so little on the commutating feature of a d-c. machine. To my mind, the commutator is the heart of the machine. If we cannot commute our load, the machine is a poor machine from an operating standpoint. If the machine is built for good operation, that is the main consideration. Now, in order to get that, we have to have the matter of commutation very, very highly considered. In certain plants, we find a certain class of commutation satisfactory, while in others, better commutation is necessary to pull a steady load. A machine may be able to carry a swinging load to very good advantage, yet that same machine through some inherent characteristics, cannot commute at its maximum load continuously.

Now that comes around to the idea of whether a machine should be complicated, as has been said, by the addition of commutating poles, or shall we simplify and thereby sacrifice commutation? Personally, I am a strong advocate for the so-called complicated machine, because a machine with its pole reversed, shows excessive wear, necessitating commutator replacements and great expense; and I think you probably have noticed that the machine that commutates black is the machine on which the up-keep is materially reduced. In other words, wear on the commutator and brushes is a minimum. I believe it has been demonstrated by actual test that the great majority of wear on commutators is due to electrical reasons rather than mechanical, and if that is true, then commutation is an important point. Now the question is, shall we compensate the commutating lines?

From my observation, I think there is a field for both machines; the commutating pole machine has its field and the compensated machine has its field. I am speaking, primarily, from a generator-standpoint and not motor-standpoint. There is very little question in my mind, but what the compensated commutating pole machine is the best machine that can be designed in the long run and will give the best service, that is, give the best continuity of service with least maintenance cost; also, that machine is probably the most economical machine. While, on the other hand, the commutating pole machine, which is simpler, has its field in applications where the heavy peak swings are not available, and I believe to a large extent that has been worked out and demonstrated in the average application in the various industries today. Now, the operating men probably have a pretty good idea along that line and will agree that the commutation problem is a very important one. I believe the selection of brushes, plays about as important a part as some of the other factors in the design of the machine. I know of a number of machines which, when not equipped with the proper brushes, would not commute worth a cent and proper brushes eliminated commutating trouble.

David Hall: I am very much interested in the question of recovery of voltage by d-c generators after sudden fluctuations of load, and I cannot quite understand why a machine with compensated winding should build up its voltage quicker than a generator with plain compound winding and without either interpoles or compensating windings. Is it not a fact that the armature circuit in the two latter cases have a higher reactance than in the case of the plain compounded generator?

A. Brunt: I would like to call your attention to one point: Mr. Hall pointed out that on the old non-commutating pole machines the limit of the output that could be gotten from the machine was determined by the commutation. Now that the commutation problem has been mastered by the introduction of interpoles, this limit has been removed. We therefore ask what then limits the maximum output that can be gotten from a certain machine? This is the heating. In this respect machines can be improved by paying careful attention to the ventilation, for which reason I

want to call attention to the great importance of ventilation in modern d-c. machines.

Paul Caldwell: There has been a great deal of discussion about use of commutating poles in generators, but little has been said about their application to motors. To my mind, commutating poles are as essential to motors as they are to generators, particularly in mill operation where these machines are subjected to the most severe service. In fact there is no service where motors are started and reversed so rapidly and frequently as in mill applications and it is to meet such severe operating conditions that the commutating pole has found its greatest field.

There is one application, however, where the use of commutating poles in series motors shows to greatest advantage and that is on the hoist motion of cranes, ore bridges and all hoisting machinery where dynamic braking is utilized for retarding the lowering load. In such applications, the machines are required to perform three distinctive functions, namely: First, that of a series motor when hoisting under any condition of load; Second, that of a shunt motor when lowering an empty hook or any light load whose weight is not sufficient to overhaul the armature: Third, that of a series generator when lowering a heavy load, which would be sufficient to produce such an overhauling effort. It is too much to expect a machine to successfully perform these widely different functions without some provision being made for commutation and especially when the loads and speeds vary over a wide range.

In many cases, such as yard cranes, ore bridges, etc., speed is a vital element in their successful and efficient operation and in lowering commutation is generally the limiting factor in the speed that can be attained. This is more noticeable where heavy loads are being handled and where the speed often reaches or exceeds 200% normal under these conditions. From tests I have made myself, I know that motors with commutating poles will handle heavier loads and permit of higher operating speeds than motors without such provision.

One of the most difficult problems in connection with adjustable-speed shunt-wound motors has been that of satisfactory commutation. This is especially true when

they are subjected to constantly varying load and speed conditions, such as machine-tool application. I believe I am safe in saying that the success of individual motor-drive to machine-tools was not attained until the introduction of commutating poles

There seems to be a growing demand for shunt-wound adjustable-speed motors of heavier construction than the standard industrial motor to meet the severe service of steel mill operations where a definite speed adjustment is desirable and where it has always been necessary to use constant-speed machines to secure the required ruggedness in construction. Based on past experience with machines, of this type, I doubt very much if they can be made to perform successfully without the use of commutating poles.

Adjustable-speed mill type motors are now available in a wide range of sizes so that the mill engineer need not further sacrifice efficiency in operation for mechanical construction where this application would warrant a limited range in speed adjustment.

David Hall: Replying to the questions which were brought up in the discussion; the grounding of an interpole coil is simply a matter of insulation. It is just as easy to insulate an interpole coil as to insulate a shunt coil; oil or water may have gotten into this particular machine, and may have been responsible for grounding the lower coil. The coil would have grounded just the same if it had been a shunt coil instead of an interpole coil.

Tests have been conducted in order to show the voltage variations on compensated machines, commutating pole machines, and non-commutating pole machines. These variations of voltage, due to suddenly applied load, are relatively very large, and of very short duration, as measured by oscillograph. All of these types of machines show a large voltage dip, due to a sudden applied load, and with 25% of full load suddenly applied, they all show a flicker on a metallic filament lamp. The fact that the voltage may recover in a few thousandths of a second does not eliminate the flicker.

The following weights of machines are given to show the progress in the design of d-c. generators:

2700 kw., 575 v., 65 r.p.m., Boston, Mass., installed in 1906, weighs 315,000 lbs.

3750 kw., 275 v., 180 r.p.m., Cleveland, O., installed in 1912, weighs 160,000 lbs.

1800 kw., 600 v., 365 r.p.m., South Bethlehem, Pa., installed in 1914, weighs 42,000 lbs.

The first machine is a non-interpole, old style design, the second machine is equipped with interpoles, the third machine is compensated commutating pole machine, and will carry a greater kw. load for a short time than either of the other machines. The weights given are for the bare d-c. generator without any prime-mover parts included. This comparison brings out two points; first, the great increase in speed which largely accounts for the great reduction in weight; and second, the improvement of the design has made possible the increase of speed. The old type of machine could not have been considered at the higher speeds. Customer is interested in the fact that he can now purchase a machine of a given kw. capacity, provided he can use a high speed at a very much lower price. This fact is mainly due to the improved design which permits large kw. output at high speed.

Some ten years ago, the first design for commutating pole generators, having a capacity of 1000 kw., were made for the Northern Aluminum Co., who was not very anxious to accept commutating pole machines, as they were new. Three months after the first four generators were installed, customer issued specifications for two more, insisting that they have commutating poles. The improvement in operation due to the commutating pole was so marked that the customer would not have machines without commutating poles.

The customer is interested in getting the best performance out of the machine for the least money expended, and the designer endeavors to accomplish this result. The introduction of commutating poles has improved the commutation to such a great extent that other factors of the design may be modified in order to produce a cheaper machine, and notwithstanding the fact that the machine is cheaper, the performance is decidedly better.

It is impossible to get as good performance out of the old type of machine. Attention should be called to the fact that the reduction in weight which has been made in recent years is not all due to commutating poles. The change from cast iron to cast steel or rolled steel for frames has been a material factor in reducing the total weight of the machine.

The efficiency of the commutating pole machine would be reduced were it not for the fact that deeper armature slots can be used, and more copper can be put on the armature, as the commutation is taken care of by the commutating pole. Also, less main field winding can be used, and the commutating pole machine is thus made equal to, or better than, the old type machine in efficiency.

THE UNAFLOW ENGINE ✓

By W. TRINKS

The trend of evolution of power supply in iron and steel plants has been to electrify every machine, up to and including the main rolls, and to concentrate the power generating apparatus in a central power house containing steam turbines in regions of cheap fuel, and gas engines (with an auxiliary steam turbine for overloads) in regions of dear fuel.

Into this evolution stepped the Unaflow engine; it now promises or threatens (depending upon the viewpoint) to change the march of events. The iron and steel plant electrical engineer is particularly interested in this problem, because a change would deeply affect his work. For him the two following possibilities are of importance: The Unaflow engine may find a place in the works power plant, or else it may drive rolling mills directly, doing away with the double conversion of mechanical into electrical power in the central station and back again into mechanical at the mill. In Germany the Unaflow engine has, in many places, been used for direct rolling-mill drive in preference to electrical drives. The question to be studied by this paper then is, what has been accomplished in the United States in the development of this type of engine, and what is the outlook for the future?

The history of the Unaflow engine begins in 1907. In that year Prof. J. Stumpf, of Charlottenburg, Germany, began his designs and applied for patents. The characteristic part of the Stumpf engine, as is well known, is the cylinder with steam admission at the ends, discharge in the center, and steam jacketed heads (see Fig. 1.) The idea of steam

admission at the ends in combination with central discharge is old and was patented to Todd in England in 1885, but the fact that the idea remained wholly unused until Stumpf proved that it was useful, when coupled with jacketed heads and a partly jacketed barrel, stamps Stumpf the inventor of the Unaflow engine from the viewpoint of the critical historian. This statement has nothing to do with the legal standpoint, whether or not Stumpf is entitled to patent protection in the United States. Decision of this question rests with the courts.

In 1907 Prof. Stumpf clearly recognized the thermal advantages to be gained from the unidirectional flow of steam through the cylinder. In the summer of that year he fully

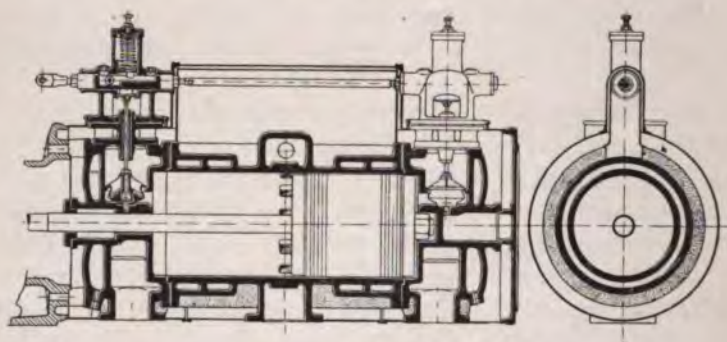


Fig. 1

explained his view upon the subject to the author of this paper at Charlottenburg, Germany. At that time the drawings of the experimental Unaflow engines were well along. From 1907 to 1911 the evolution of that type of engine was limited practically to Austria and Germany. In 1911 Prof. Stumpf published his well-known book on the Unaflow engine, and bitter literary controversy on the merits or demerits of the Stumpf engine followed. In the same year American engineers began to take notice of the Stumpf engine and, one by one, the C. & G. Cooper Co., the Nordberg Manufacturing Company, the Mesta Machine Co., the Skinner Engine Company, and the Ames Iron Works took up the building of this type. A great deal had to be learned by these firms and some of the experience was quite dearly paid for.

At the present date, the period of experimenting is practically over, and the time is ripe for a review of the situation.

The principal claims for the Unaflow engine are economy, simplicity, reliability and freedom from attendance.

Let us consider these features in the order mentioned and then judge whether we can profitably use the Stumpf engine in our work.

In the steel works power plant this engine will have to compete with the gas engine and with the steam turbine. The gas engine uses 7,500 to 9,500 b.t.u. per indicated horsepower-hour, whereas the Unaflow engine, running condensing, uses from 11,000 to 13,500 b.t.u. in the steam, and more in the fuel gas, depending upon the boiler efficiency. There is, in consequence, little hope of replacing the gas engine by the Unaflow engine.

When we come to a comparison between the engine and the turbine, variation of steam pressure and of back pressure make it advisable to leave the b.t.u. basis and to introduce Rankine cycle efficiency, which means the ratio of the work actually produced from unit weight of steam to the work which could be produced by the same weight of steam passing through the Rankine cycle. From a great number of published tests made on the very best turbines, the author has formed the following averages for condensing operation:

Size of turbine, kw.	500	1000	2000	5000	10,000
Rankine cycle efficiency	.62	.66	.71	.77	.82

(Referred to Brake h.p.)

For non-condensing operation the values are much lower.

For the Stumpf engine, data furnished by the Stumpf Unaflow Engine Company, tests made by the author and data from Ames Iron Works and from the Cooper Company indicate the following efficiencies:

Size of engine, Kw.	300	600
From 3 lbs. per sq. in. back pressure above atmosphere down to about 23" vacuum.		
Efficiency		
(Saturated	71	74
(100° Superheat	75	77
(200° superheat	78	79

For high vacuum (about 27½")

(Saturated	58	62
(100° superheat	62	65
(200° Superheat	66	68

The values may vary somewhat to one side or the other, but the general tendency is apparent. For non-condensing operation, for 100° superheat, for moderate vacuum, and for sizes up to 1000 kw., the Unaflow engine is more economical than the turbine. It will, therefore, find a place in comparatively small power plants and in such locations where 28" of vacuum or better is not attainable. It will also be preferred for generating direct-current, because turbines for the generation of direct-current, when direct connected, are too slow for best economy. If they are to operate at economical speed, gears must be introduced.

Evidently, the Unaflow engine will have a very limited field in the steel works power plant. Turning to the second application which interests us, namely, the driving of rolling mills, we find a changed condition. Let us here, for the sake of clearing up doubts, compare the Unaflow engine with electric drive and with the older type of duoflow engine. In comparison with electric drive, the steam engine does away with the electric generator, the switchboard, the transmission line and the motor, but it takes undesirable piping into the mill. The elimination of the electrical part means that we must compare the Rankine cycle efficiency of the engine to the Rankine cycle efficiency of the turbine, including generator, transmission line and motor. Allowing the high efficiencies of 92% for the generator, 98% for transmission line and 92% for the motor, we must multiply the turbine efficiencies by .83 for comparison with the direct-connected engine. This procedure furnishes:

Size of turbine, kw.	500	1000	2000	5000	10,000
Rankine cycle efficiency					
referred to motor shaft	50	54	59	64	68
referred to mill shaft	47	50	55	60	64

The lower row of figures was obtained by multiplying the upper row by .965 x .965, this figure taking care of the efficiency of two speed reductions from the motor to the mill. A study of the resulting values shows that the Unaflow en-

gine is ahead of the electric drive, unless the steel plant is so large that turbo units of over 8000 kw. capacity can be installed.

The economy of the Unaflow engine compared to that of the steam-turbine-electric drive, taken by itself, is not enough better to explain why the Unaflow engine should fare differently from the compound engine. The Rankine cycle efficiency of a good compound engine is practically the same as that of the Unaflow engine, but there is one vital difference: To obtain that high efficiency, the compound engine

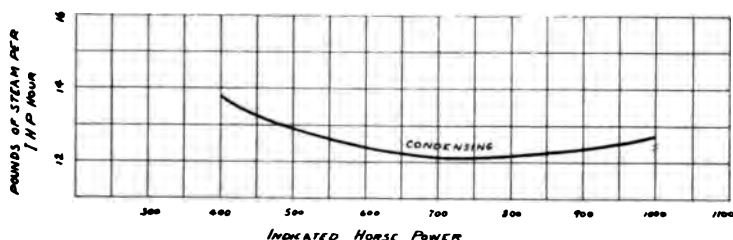


Fig. 2

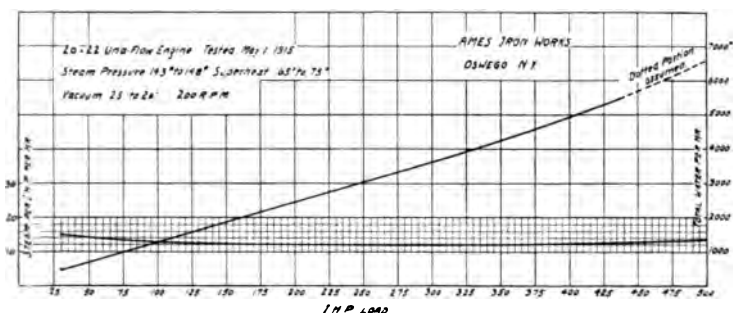


Fig. 3

must have a small high pressure cylinder (which cuts down condensation area); but the small size of the latter means a small overload capacity, and quick departure from best efficiency for comparatively small changes of load. Fig. 2 illustrates the water-rate-against-load curve for a well known compound engine. Comparison of this curve to the typical water rate curve of a Unaflow engine, Fig. 3 (Ames Iron Works), shows the difference to be very marked. Mill loads are notoriously variable, because small variations in

draft, temperature of steel, velocity of rolling, etc., cause disproportionately great changes in resistance. It is not possible to exactly foretell what the load will be and it is therefore of the utmost importance to secure a drive which permits over or under-loading without serious change of economy. The Unaflow engine, and the electric motor, hitched to a large central station, both fill this requirement. The compound steam engine does not.

The old type simple duoflow engine, the old reliable standby of the rolling mill for over fifty years, cannot be considered here. It is so wasteful, that its low price is more than offset by increased cost of boiler house equipment, not to mention the continuous cost of fuel and water. It retained its place in the mill a long time, due to its simplicity; it was replaced here and there by the compound engine on account of its wastefulness. The Unaflow engine combines the simplicity and overload capacity of the simple engine with the economy of the compound engine; it has the added advantages that its overload capacity is even greater than that of the simple engine and that its economy is sustained over a greater range of load. Finally, it has very few moving parts and takes up much less floor space than the compound engine.

Variation in back pressure naturally affects the operation of the Unaflow engine. However, the vacuum may (with 4% clearance) vary from 19 to 27 inches of mercury without unduly high compression, or pounding (due to lack of compression).* If the vacuum fails altogether, clearance is automatically added, to keep the compression down.

It would be very interesting at the present time to compare, from actual installations, the cost of a Unaflow engine drive with that of an electric drive. Unfortunately, there are as yet too few installations of mill Unaflow engines in the United States to make such a comparison. However, the author knows from personal experience that a Unaflow engine with d-c. generator costs less than a geared steam turbine with generator. From that it may be concluded that an engine without generator, direct connected to the

*According to experience of C. & G. Cooper Company.

mill, will cost less than a turbine plus generator, plus switch-board, plus motor, plus gear drive.

A great deal has been written on the reasons for the economy of the Unaflow engine; nevertheless the author will try to present the underlying facts again in as concise form as possible. The secret of the economy of the Unaflow engine lies principally in reduction of internal cylinder condensation. In the duoflow single expansion engine, cylinder condensation is so great, that a very great free expansion loss must be allowed for best economy (or rather for minimum wastefulness). In the compound and triple expansion engine, cylinder condensation is reduced so that the free expansion loss can also be reduced, but mechanical losses due to the passing of the steam through so many valves become great. In the duoflow engine, cylinder head, cylinder barrel and piston head are alternately heated and cooled by live steam and exhaust steam sweeping over them and wiping heat "on and off." In the Unaflow engine, only the piston head has heat wiped off during the extremely short period of exhaust, the steam near the place of entrance of live steam being at rest like the fixed end of an expanding coiled spring during exhaust, and like that of a compression spring during compression. Besides, the cylinder head and part of the barrel are steam jacketed, and steam jacketed surfaces are cooled very little by stagnant steam. It may be remarked again that the mere provision of a central exhaust does not bring about a successful Unaflow engine; the steam jacketing of the heads and of part of the barrel must go with it, to produce the thermodynamic superiority over the duoflow engine.

In the duoflow engine, long compression means increased steam consumption, principally, because the steam temperature exceeds the cylinder (or piston) wall temperature a longer time than it would with shorter compression. In the Stumpf Unaflow engine the steam which is being compressed is in contact with progressively hotter surfaces, with the exception of that of the piston, and the steam temperature never rises very much above the wall temperature.

The second reason for the economy of the Unaflow engine lies in the enforced or compulsory tightness. Steam cannot leak from the live steam space to the exhaust. If

the inlet valves are leaky to any extent, the compression rises so quickly that the inlet valves clatter and give notice to the engineer that something is wrong.

In comparing test data with calculation results, I have obtained very good results by using Heck's formula for the internal condensation or missing quantity (Heck, the Steam Engine and Turbine, paragraph 22), but I substitute instead of his constant C the value $C - \sqrt{\frac{^{\circ}\text{F superheat}}{4500}}$ for duo-flow engines, and $.45 C - \sqrt{\frac{^{\circ}\text{F superheat}}{10,000}}$ for Unaflow engines.

The development of the Unaflow Engine in the United States has been slow, probably because it did not fit into the general trend of changing from reciprocating to rotating machinery, and because it is of foreign origin. It began in a small way in 1912. The C. & G. Cooper Company, of Mount Vernon, Ohio, the Nordberg Company, of Milwaukee, Wisconsin, and the Mesta Machine Company, of Pittsburgh, Pa., began almost simultaneously to build experimental engines. All three firms moved cautiously and equipped their engines with the "old, reliable" Corliss gear; all three found out that the Corliss releasing gear, in its usual form, is not ideal for the Unaflow engine, because the cut-off is so short, because modern plants carry high pressure with superheat, and because the pressure drops so fast after cut-off, that the valve becomes unbalanced too quickly for the ordinary design and size of vacuum pot. In consequence, the Mesta Machine Company and the Nordberg Company switched over to poppet valve gears, while the Cooper Company adapted their Corliss gear and vacuum pot to the new conditions. The Mesta Machine Company, licensed by the Stumpf Unaflow Engine Company, made their poppet valve gear non-releasing, see Fig. 4, while the Nordberg Company adopted a releasing gear. The latter type of gear did not find favor with German engineers on Unaflow engines; they claim that it is not adapted to the short cut-off required; it remains to be seen whether the skill of the engineers of the Nordberg Company has overcome the alleged difficulties.

The smaller sizes of Unaflow engines have been developed by the Ames Iron Works, of Oswego, N. Y., and by the Skinner Engine Company, of Erie, Pa. The Ames Iron Works are licensed by the Stumpf Unaflow Engine Company,

holders of the Stumpf patents. The Ames Iron Works, from the very beginning, adopted poppet valve steam distribution, with shaft governor drive, see Fig. 5. This design is very well adapted for small engines up to 400 or 500 h.p., and is

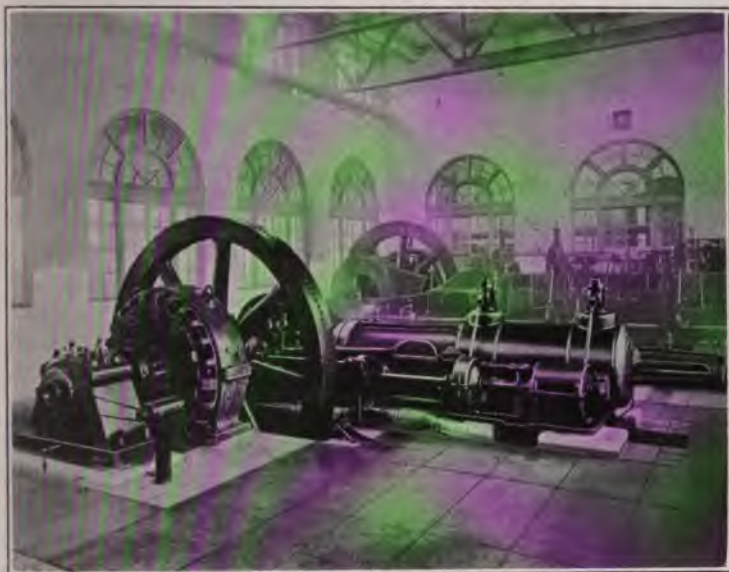


Fig. 4

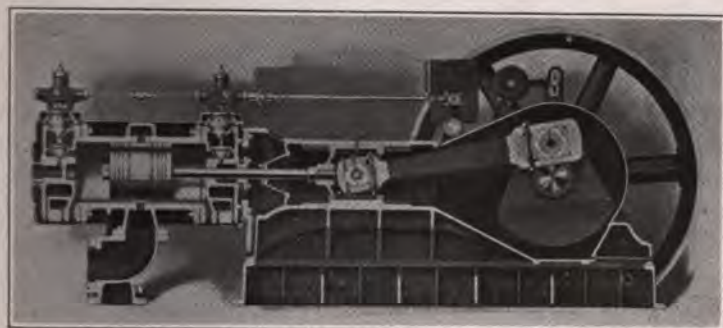


Fig. 5

very successful. For larger sizes and high steam temperature it is not so well adapted, because the difference in expansion between the valve rod and the cylinder becomes too

great and disturbs steam distribution. For poppet valve engines above 500 h.p. the lay shaft drive, such as shown in Fig. 4, is preferable.

In the sizes built by the Ames Iron Works, a self supporting piston, guided at the crank end only, is perfectly satisfactory (see Fig. 5). In larger sizes this same design leads to a great deal of trouble. On account of difference in expansion, the piston must be very loose fit in the cylinder. The guiding of the piston by the crosshead is very imperfect. The piston, therefore, wobbles around in the cylinder, riding now on one spot, then on another, never wearing itself

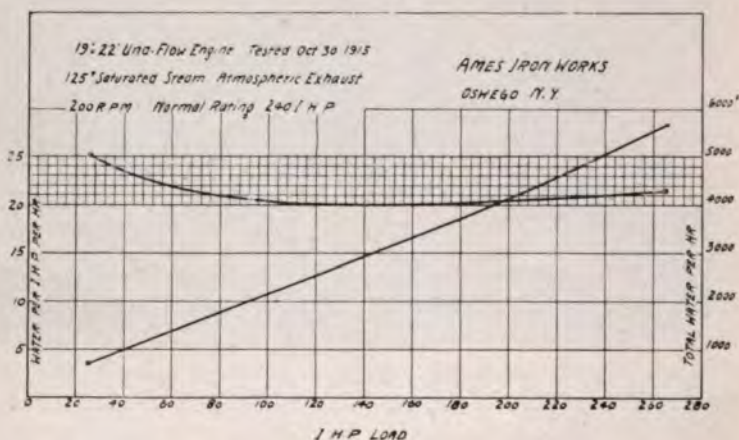


Fig. 6

in, but rapidly wearing itself out. In large engines of German design, a tail rod guide has been provided, not so much for the purpose of carrying the piston, but mainly for the purpose of guiding it, so that it will always touch the cylinder in a large surface. American engineers have gone one step further and have made the piston-rod strong enough to carry the piston.

The early part of the practical development was thorny. Cracked cylinders, heads and bed plates caused trouble; valve gear troubles and regulation troubles had to be overcome, pistons and cylinders wore too rapidly. But the problems have all been solved and the future promises to be free from any obstacles whatsoever. Whatever troubles were

experienced, naturally appeared more forcefully in the larger sizes, with the result that the smaller sizes, developed by the Ames Iron Works and the Skinner Engine Company have made more progress in numbers than the larger sizes. It can safely be said that the UnafLOW engine to-day is as reliable as the simplest engine of the duofLOW type.

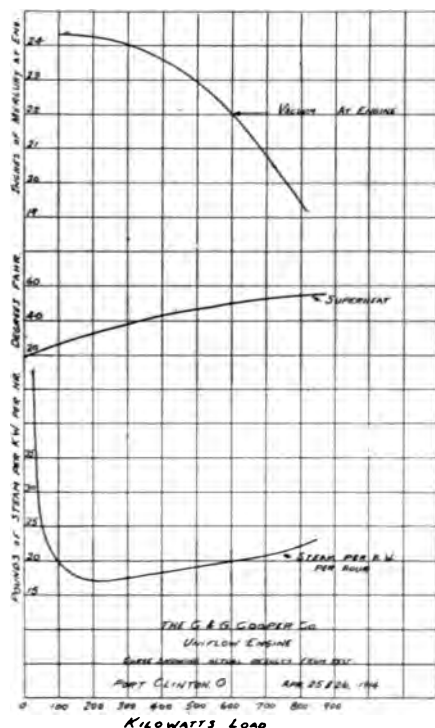


Fig. 7

In conclusion, a few additional steam consumption charts may be appreciated. To the scientific engineer they do not mean as much as Rankine cycle efficiencies, but habit has led many of us to think in pounds of steam per horsepower-hour. Consequently, Figures 6 and 7, are given, showing steam consumption of various types and sizes of UnafLOW engines.

DISCUSSION

S. C. Coey: The subject matter of this paper is very interesting to me as we are just installing two large Nordberg Unaflow engines for merchant mill service at the Youngstown Sheet & Tube Co., a brief description of which may be of interest.

The largest of these has a cylinder diameter of 44" with a 50" stroke with side crank frame designed to operate at speeds from 65 r.p.m. to 110 r.p.m. When running at 110 r.p.m. this engine will develop a normal h.p. of 1400 b.h.p. and a maximum h.p. of 2100 b.h.p. This engine is designed to run condensing with a vacuum varying from 20" to 24" and a normal steam pressure of 170 lbs. gauge and 75° superheat at the inlet valve, the maximum conditions being 200 lbs. steam and 100° superheat. The guarantees on this engine when running under normal steam pressure and a vacuum of 24" maintained at exhaust nozzle are as follows:

B. H. P.	350	700	1050	1400	1750	2100
Lbs. Steam I.H.P	13.6	12.6	12.25	12.55	13.10	13.65
Lbs. Steam b.h.p.	17.5	14.4	13.4	13.45	13.85	14.3

This is a thermal efficiency of about 71% Rankine Cycle at full load and equal to the results obtained in good turbine practice. The interesting feature of this type of engine as applied to rolling mill conditions is that the efficiency holds up under a wide range of load. In this case the guarantees from 50% load to 150% load show up very favorably. It is interesting to note that this is the largest Unaflow engine that has ever been built in the United States and the results of the tests showing actual operating data will be of great engineering value. This engine will operate on a 12" merchant mill.

The smaller of the two engines has a cylinder diameter of 37" with a 48" stroke with side crank frame designed to operate at from 55 r.p.m. to 110 r.p.m. When running at 110 r.p.m. this engine will develop a normal h.p. of 1000 b.h.p. and a maximum h.p. of 1500 b.h.p.

This engine is designed for the same conditions of operation as the 44" x 50" engine and when running under normal steam pressure and a vacuum of 24 "maintained at

the exhaust nozzle the guarantees are as follows:

B. H. P.	250	500	750	1000	1250	1500
Lbs. Steam I.h.p.	13.55	12.45	12.30	12.70	13.30	13.90
Lb. Steam B.h.p.	17.6	14.3	13.5	13.7	14.1	14.6

As in the case of the larger unit I would call your attention to the wide range of efficient operation.

Mr. Trinks has called attention to the fact that we have become accustomed to talking in terms of lbs. of steam per kw-hr. or per i.h.p-hr. and points out the fact that the Rankine cycle efficiency is a better method of comparing the efficiency of prime movers. This is true not only in determining what type of prime-mover shall be used, but also in determining whether power shall be bought or not. I have often heard good engineers say they could not afford to generate power because their turbines took 20-lbs of steam per kw-hr. while the central station could generate at about 13-lbs. The older installations in steel plants usually are operated at 150-lbs maximum gauge pressure at the boilers. The modern central station has taken advantage of high steam pressure and superheat to gain the extra percentage that can be obtained by using the higher boiler pressure. The Rankine cycle efficiency of a turbine operating at 200-lbs. gauge saturated steam with 29" vacuum and a water rate of 13.0 lbs. per kw-hr. is just the same as that of a turbine operating at 150 lbs. gauge saturated steam with 26" vacuum and a water rate of 16.6 lbs. per kw-hr. or of another unit running at 150 lbs. gauge saturated steam against 5 lbs. gauge back pressure with a water rate of 30.9 lbs. per kw-hr. In each case the Rankine cycle efficiency is 70%. In the latter case the low pressure steam might be needed for some special plant operations and the idea that the machine was inefficient would be erroneous. In going to high steam pressures and superheat it is possible to gain a few per cent. in overall efficiencies but nevertheless it does take more coal to bring steam up to 250 lbs. gauge pressure with 100° superheat than it does to make saturated steam at 150 lbs. gauge pressure. When we compare water rates indiscriminately we assume that as much of high pressure superheated steam can be developed from a pound of coal as is developed at the lower pressure. The

diagram (Fig. 8) shows a simple method of determining the Rankine cycle efficiency of any unit very readily. A ruler from the left hand line showing pressure to the right hand line showing vacuum will give the theoretical water rate of a perfect engine. This divided by the actual water rate gives the Rankine cycle.

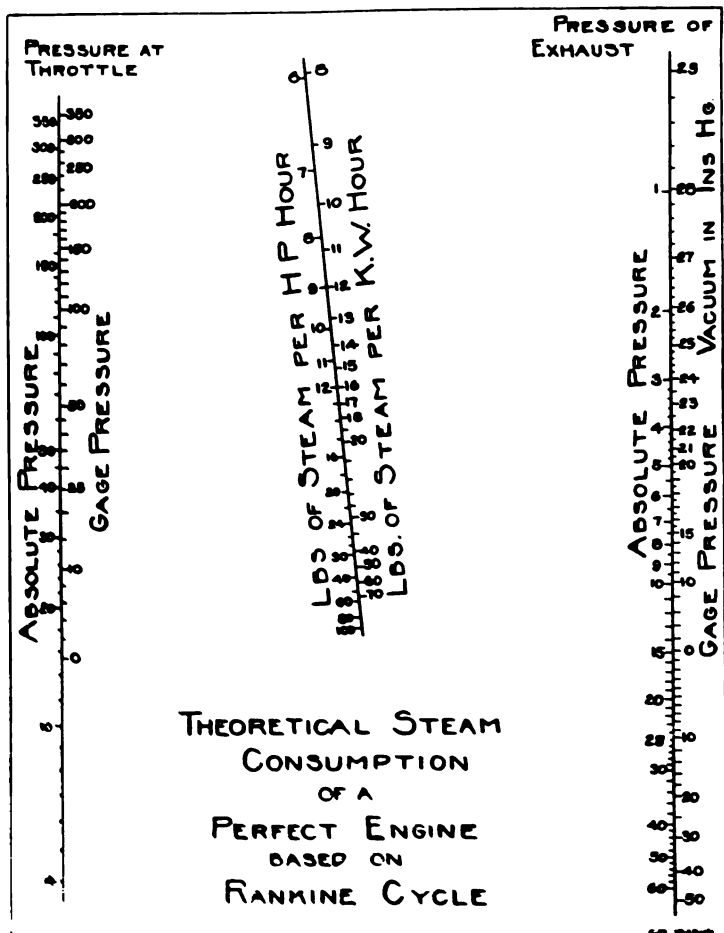


Fig. 8

This body of men is interested in the best prime movers. If the Unaflow engine lives up to expectations it will probably be widely used in the future for main roll drives near the source of steam supply especially on intermittent loads such as sheet mill, merchant mills, continuous skelp

mills, etc. However, the other factor must always be borne in mind that the transmission of steam over any great distance is inherently inefficient. Consequently mills at a considerable distance from the source of steam supply will be driven by motors whether the prime mover for the generations of power be a turbine or a Unaflow engine.

In transmitting steam the loss is represented by the amount of heat that is radiated from the steam line and the amount of heat that goes down the sewer from the traps in the line.

In electrical transmission if we get a difference in temperature of more than 32° between the copper and the outside air we consider that we are running inefficiently. This represents in a nutshell the difference in efficiency of transmission by steam and electricity.

G. C. Emmons: Professor Trinks has shown that, in instances where turbine generators of over 8,000 kw. are not warranted, the Unaflow engine will drive rolling mills with greater economy than will be secured with motors driven from turbine generators.

Say, therefore, we elect to install Unaflow engine driven rolling mills and consider for the moment the effect of modern steam conditions and the Unaflow engine upon our steam transmission losses.

We are daily adopting higher steam pressures and higher superheat, for both make for increased economy, whether the units are of the turbine or reciprocating type. Both these factors increase the steam temperature and, therefore, the radiation losses per square foot of pipe surface are increased.

As Professor Trinks has pointed out, another characteristic of the Unaflow engine is its very short cut-off. If we connect the boilers or steam header to the engine throttle with a constant size steam range proportioned for an average velocity of, say, 6,000 ft. per minute, we will find that we obtain a greater pressure drop with a Unaflow engine than with a Duoflow engine for the reason that the maximum velocity of flow in the range varies inversely as the cut-off, and the pressure drop varies as the square of the velocity.

From the above it is seen that it is advisable to employ a large receiver separator on the throttle valves of Unaflow rolling mill engines. This permits the engine during the period of admission to receive steam from the large wall of the separator, which when properly proportioned for the actual installation will enable it to draw from the range at a nearly constant velocity. Advantage of this feature may be taken to materially reduce the size of the steam range without undesirable pressure drop and with consequent reduction of radiation losses.

Such a separator will also prevent water slugs, caused by foaming and priming boilers, from entering the cylinders where considerable damage might result, especially in the condensing or small clearance Unaflow engine types.

Joseph Breslove: The Unaflow engine undoubtedly presents some interesting features which should prove of value in certain special cases. Mr. Trinks has brought out some of these points, but the true value can only be determined after a greater number have been put in service and actually tested in the field.

The water rate curves showing the comparative economy of the Unaflow and the Corliss engines, as indicated in Figures 2 and 3, are hardly fair to the latter. It must be noted that the two curves in question are drawn to entirely different scales. Each vertical ordinate on the Unaflow diagram represents 10 pounds, whereas the same ordinate on the Corliss curve represents only one pound. The horizontal scale is also in favor of the Unaflow in the ratio of 2—1, so that while the steam consumption curve of the Unaflow engine is shown very flat, it is not a true comparison with the Corliss. It is also a well known fact that at light loads the Unaflow curve rises abruptly, as is shown in Fig. 7 and not as shown in Fig. 3.

It is now recognized that the provision of a central exhaust must be supplemented by steam jacketing of the heads and parts of the barrel to make a successful Unaflow engine. This method of improving the economy of a steam engine is not new, the practice of jacketing having been adopted many years ago by builders of Corliss engines where the highest economies were demanded. A compound engine having steam-jacketed heads and barrels and operat-

ing under the same steam conditions as the Unaflow, for which the water rate curve is shown, viz., about 145 pounds gauge steam pressure, 65 to 75 degrees superheat and 25" to 26" vacuum, would develop an I.H.P. hour at normal load of not more than 11.75 pounds of steam, but the Unaflow at the same normal would be 12.5.

For non-condensing service, the Unaflow engine is superior to the steam turbine, but is not as economical as the compound non-condensing Corliss engine. It is only for con-

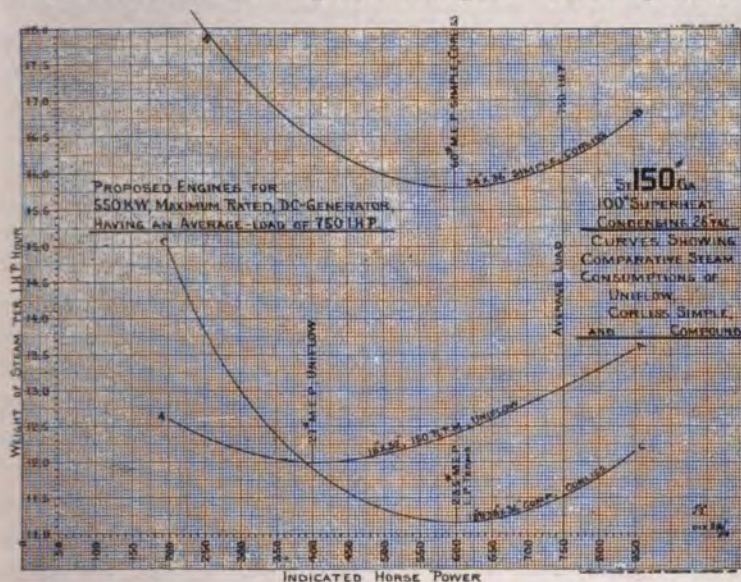


Fig. 9

densing service at moderate vacuums that its economy is comparable to the compound Corliss. For comparatively small high speed units in conjunction with direct connection to electric generators, on account of the high speed possibilities, it undoubtedly has an important field, for the reason that the high rotative speed permits of a smaller engine, smaller generator and consequent lower first cost. This will, of course, also hold in the case of high speed engines of other makes. When we consider the problem from the standpoint of larger units, the Unaflow engine has no special advantage. I have here a curve, (Fig. 9) showing the comparison of a 28" x 32" Unaflow engine and an 18"

and 38" x 36" compound Corliss, as proposed for 550 kw. max. rated d-c. geenrator to carry average load of 750 I.H.P. It will be noted that at the best load conditions the compound Corliss is about .85 pound better than the Unaflow, whereas at average load conditions, the difference in favor of the compound is even more marked. In the particular case for which these curves were drawn up, the figures represent the steam consumption guaranteed by the respective manufacturers, the average operation was to take place at approximately double the load at which the Unaflow engine gave its best economy, and consequently, when operating at or near the average load, the economy of the Corliss engine would more than offset its slightly greater first cost. It will be noted that the Unaflow curve, which is plotted from a guarantee given by a well-known builder of Unaflow engines, is far from being flat and that the engine must be operated far below its maximum rating for best performance.

The Ames Company condensing ratings are based on 15% cut-off and best economy at 71% of rated load, and the non-condensing ratings based on 20% cut-off and best economy at 62.5% of rated load; that is, the Unaflow engine is rated to give its best economy at about two-thirds maximum load, or, in other words, it is possible to supply a smaller compound engine, and thus reduce the first cost, if the best economy at two-thirds the maximum rating is desired. The simple engine is admittedly not as economical as the Unaflow, but costs less. But with a compound Corliss, while it costs slightly more than the Unaflow, when carrying the average load, about 9% better steam consumption can be obtained, namely 12.25 for Unaflow and 11.15 for compound.

The reliability of the Corliss engine is unquestioned and is a simpler engine than the Unaflow. The piston is comparatively light and the cylinder short, so that it is not necessary to install tail rods on as small engines as in the case of the Unaflow where the long piston entails considerable weight, which must be taken care of, and the long cylinder with central exhaust ports is more difficult to keep in line. The operation of large Unaflow engines has not yet demonstrated that it is likely to be as free from operating difficulties as the Corliss engine. It is true that for very high de-

degrees of superheat it may be advisable to furnish poppet type valves for the high pressure cylinders, but superheat used in Corliss engines up to a total temperature of 500° F. has proven perfectly satisfactory and are in common use in the United States.

The trend of recent practice has been towards the centralization of power production, electric transmission and motor application to the machines. In most instances high vacuum is possible and the steam economy of large turbo units has reached a point that is particularly gratifying. While it is true that the transmission lines and the electrical conversion entails some loss in economy, the flexibility which is possible with electric drive goes far toward off-setting this factor. Assuming that individual engines with long steam lines would give the same economy, which in most cases is doubtful, it is hardly probable that the trend will be toward a decrease of large power units and electric drive in favor of direct engine connection.

F. D. Egan: The author in his discussion of Rankine cycle efficiencies does not state clearly whether his basis of comparison is indicated or brake horse-power. This point is very important, as the mechanical efficiency of a high speed rotary unit is materially higher than the slow speed reciprocating type, and what we are finally interested in is the thermo-dynamic efficiency or the ratio of heat applied at the shaft or belt to the heat supplied to the engine. Neither does he include the steam lost in jacketing nor the efficiency of steam transmission.

Notwithstanding that the Unaflow engine shows better Rankine cycle efficiencies than turbines of 8,000 kw. capacity, as stated by the author, the turbine is a far more economical heat unit. The Rankine cycle for reciprocating engines expands the steam to release pressure, whereas the cycle for the turbine expands to exhaust pressure. There remains, therefore, to the turbine heat available which cannot be utilized by a reciprocating engine, or in other words, the turbine is capable of taking the used steam of a reciprocating engine and converting part of its heat into mechanical energy.

Manufacturers will guarantee water rates of 14.1 lbs. per kw-hr. at terminals of the generator of a 5,000-kw. tur-

bine, operating on 175 lbs pressure, 125° F. superheat, and 28" vacuum. This corresponds to a Rankine cycle efficiency of 73% referred to brake horse-power, and gives the total heat used per horsepower-hour at the terminals of the generator as 12,800 b.t.u.

The author's curve, Fig. 3, for a 20" x 22" Unaflow engine operating with 145 lbs. pressure, 70° F. superheat, and 25.5" vacuum, shows 12 lbs. per indicated horsepower-hr. which gives a heat consumption of 14,200 b.t.u. per indicated horsepower-hour. Referred to the mill shaft, the heat consumption for the turbine with direct connected motor drive would be $12,800 \div .92 \times .98 = 14,200$ b.t.u. and for the Unaflow engine $14,200 \div .85 = 16,700$ b.t.u., assuming 85% as the mechanical efficiency of the engine.

In addition, the loss in the transmission line from the boiler house to the engine will be at least 5% higher than the loss from the boiler house to the turbine. This is due to the fact that the power house will be located adjacent to the boiler house, while the Unaflow engine when used for driving non-reversing mills will necessarily be located some distance from the boiler plant. This factor will increase the heat consumption of the Unaflow engine at the mill shaft to 17,580 b.t.u.

The author draws a comparison between the cost of a Unaflow engine with direct current generator and a geared turbine with generator and concludes that an engine without generator, direct connected to the mill, will cost less than a turbine, plus generator, plus switchboard, plus motor, plus gear drive. In discussing this point, we must not lose sight of the fact that in comparing a direct connected engine unit to a direct connected motor drive on the main rolls of a mill, that, while we must include in the cost of the electric drive the total cost of the motor, we do not have to include the total cost of a turbine, generator, switchboard, or transmission line. Due to the diversity factor of the total electrical load in the mill referred to the power plant, we must include a turbine, condenser, generator and transmission line capacity to about one-third the capacity of the main mill motor, and not over ten per cent. of the cost of a switchboard panel equal to the capacity of the motor. While comparing this cost, the author failed to include in the case of

the engine drive, the additional cost of an air pump, motor driven circulating pump, and condenser to the cost of the engine. This would be chargeable in total against the engine, while at the power plant only one-third of the cost of the condenser would be chargeable to the motor cost. In fact the condenser at the power plant would be installed whether the particular mill was steam or electric driven. Under these conditions of comparison, the difference in cost would be in favor of the motor rather than the engine drive.

The condensing plant for the engine used in driving a mill would not be as large as the one at the central power plant, consequently it would not operate as efficiently, due to the smaller size of the air and circulating pumps. In making the steam distribution charges for the air pump, at least twice the amount of power would have to be charged to the isolated condensing plant in the mill as would be required in the case of the electrical driven mill. This increase would have to be charged to the engine drive and would further increase the b.t.u. value at the mill shaft.

As even better heat economy can be obtained from the turbine by the use of higher pressures, temperatures and vacuums that I have used in making my comparison and considering the points the author has failed to consider, it is evident that the UnafLOW engine neither promises nor threatens to eliminate the electric motor as a main mill drive, nor compares with the turbine unit in the power house of a modern steel plant. Not only is there available about 3,500 to 4,000 b.t.u. per h.p.-hr. by use of electric drive on the main rolls, but the constant torque which this drive gives, together with its ease of control, freedom from attendance and repairs, makes it altogether the drive to be desired for this duty.

J. H. Wilson: A large part of our talk this morning has been composed of a comparison between the UnafLOW engine and other engines for steel mill drive. The last discussion brought the electrical installation for consideration.

Ease of control has forced the substitution of motor drive for engine drive on steel mills.

The efficiency of boiler house and steam power units is directly related to the uniformity of steam requirements.

Rolling mill loads fluctuate, the extremes being the sheet mill in one case, and the blooming mill in the other. The blooming mill runs idle a varying percentage of the time. The sheet mill is seldom running idle. The peak load on a blooming mill varies at any time, while on a sheet mill it is varied but few times. The relation of the peak load to the average load has brought in the question of fly-wheels, with the idea of taking up the difference between the average and peak by deriving energy from the fly-wheel. In case of a reversing mill this fly-wheel would be located on the generator end.

In order to take energy from the fly-wheel, the fly-wheel must be arranged to slow down. This, when connected to an induction motor, means that the rotor of this motor must be wound to give considerable slip at the average load, or separate resistance must be cut in to provide the necessary slip.

A couple of years ago, at one of our conventions, it was argued that as additional slip of the motor resulted in reduced efficiency, we should find a motor of lower resistance to have higher efficiency. This argument is undoubtedly correct taking the mill only into consideration. In most installations, however, the size of motor to be used, and the amount of energy to be taken by the fly-wheel must be referred to the electrical power station and not decided solely on the requirements of the mill. For example, we might have a mill installation that would require a peak load of 4000 h.p., and an average load of 1500 h.p. If this equipment obtained its power from a station having a capacity of 50,000 h.p. and above, it might be advisable to use no fly-wheel at all, but put a motor in having an overload capacity that would handle the peak with a small amount of slip on the slowing down of the mill. If this same equipment was to be supplied from a power station having a loaded capacity of 5000 or 6000 h.p., and average of 10,000 or 12,000 h.p., it would work out best to carry considerable of the power on the fly-wheel because the electric load would be too great in proportion to the capacity of the power house to permit of taking it all on the motor.

Most plants have more than one mill and as a result, to compare the electric drive and engine drive we must not

base our arguments on the condition of one mill alone, but on the conditions of the whole plant, as much of the advantage of motor drive is included in ease of power transmission, elimination of losses when mills are down, questions of control, and in the final analysis, the amount of coal burned.

By the proper use of fly-wheels with electrical control on motors, sheet mills, jobbing mills, and merchant mills, motor generator fly-wheel sets in blooming mills, the electric load can be made a very steady demand on the turbines in the electrical power station, which in turn must use efficiency in the operation of each turbine unit, and high efficiency in the operation of the boiler house and other steam producing equipment.

In considering steam distribution, the losses due to condensation and leaks, conditions even where mills are shut down over week-ends, these losses amount to a great deal of money in the long run. With electric distribution, losses vary with the power used, and when the power is cut off, the losses stop.

I was much interested in the discussion of the installation of a Unaflow engine with a capacity of 1400 h.p. The efficiency of this engine at low load was irregular and as Prof. Trinks has found, there is undoubtedly very many places where the Unaflow engine can be applied with advantage to rolling mill work.

T. E. Tynes: I would like a little information on what is a fair percentage of transmission losses in the steam line of a given capacity, say a steam line supplying 1,000 h.p. What is a fair percentage of radiation losses, condensation losses, per hundred feet of line? Every person I have talked to has a sort of hazy idea on that subject, there is nothing definite. If any member of the Association has any figures along that line, I would like to get an idea of what they are.

W. Trinks: The heat loss which is caused by steam lines, varies with the nature and thickness of the covering and with the extent of the covering. If valves and flanges are left bare, the heat loss is much greater than if these parts are covered. For well-covered lines, the relative heat loss may be found in the following manner, which covers average conditions:

Diameter of engine cylinder = D . Mean effective pressure = 35 lbs. per sq. in. Piston speed = 800 ft. per min. Steam consumption per brake horse-power hour = 15 pounds. Then steam per hour

$$\text{equals } \frac{3.1416}{4} D^2 \times 35 \times 800 \times 15 \div 33,000 \text{ equals } 10D^2 \text{ pounds.}$$

Diameter of steam pipe $d = \frac{1}{5} D$. Consider length of steam pipe equal to ten cylinder diameters. Then heat loss per square foot, degree Fahr. and hour equals .45 b.t.u., which, for 350 deg. F. temperature difference gives the loss per hour as:

$$3.1416 \frac{1}{5} D \times \frac{10D}{144} \times .45 \times 350 = 6.9 D^2 \text{ B.t.u.}$$

With 1100 b.t.u. per pound of steam, the loss in pounds per hour is $\frac{6.3}{1000}$ pounds of steam. The loss in per cent. then is:

$$\frac{6.3 \times 100 \times D^2}{1000 \times 10 \times D^2} = \frac{6.3}{100} = .063 \text{ per cent}$$

This refers to a steam pipe length of 10 cylinder diameters. To make the loss equal 1%, the length of the steam pipe must be 160 cylinder diameters. This calculation assumes that engine works all the time at rated load.

Referring to Mr. Breslove's remarks, I wish to say that the scales on Figures 2 and 3 of steam consumption of duoflow and unaflow engines, were not intentionally distorted. The original curves from which the illustrations were prepared happened to be drawn to these scales.

With regard to jacketing of heads in duoflow engines I can positively state that it is not to be recommended except in slow-speed engines. Triple expansion reciprocating engines are benefitted by having heads and barrels jacketed. high speed duoflow engines are not, for this reason: Whatever heat we transmit through the jackets into the steam during the exhaust period is lost to the exhaust steam; whereas in the unaflow engine very little of the heat which is transmitted through the cylinder head or the admission part of the barrel reaches the exhaust. During exhaust the steam at the admission end of the unaflow cylinder is prac-

tically stagnant, whereas in the duoflow engine steam flows along the steam jacketed surfaces, wipes off the heat and carries it into the exhaust. For that reason steam jacketing of duoflow engines has been abandoned except in cases where the heat imparted to the exhaust steam still does good work in the next cylinder.

Mr. Breslove contrasted the Corliss engine and unaflow engine. I think that that is based on wrong reasoning. What we should do is to contrast the unaflow engine and the duoflow engine. The Corliss engine is but one of many duoflow engines and it is one which is rapidly disappearing from the field of power generation. The appearance of the steam turbine has raised steam pressures and steam temperatures, which fact has made the use of Corliss valves highly undesirable except on low pressure cylinders. Corliss valves distort under high temperatures and groan considerably. They can be quieted down by excessive use of oil, and it has been stated that Corliss engines are successful on high superheat if you have an oil refinery right alongside of them. Consequently, Corliss valves should not be used in modern power plants in high pressure cylinders, no matter whether the engines are of the unaflow or duoflow type, but the valves should be of the poppet or piston type.

When it comes to the largest size of cylinder which can be used on unaflow engines, then I can state that there should be no trouble even with the largest diameters, provided that you utilize the experience of European builders. The sad experience which we have had with several unaflow engines in this country originated very probably from the fact that our engine builders preferred getting their own experience to paying for someone else's experience. In Germany there are unaflow engines in successful operation developing as much as 6,000 h.p. in one cylinder. The builders of this large engine, whose plant I visited, stated positively that they had no trouble whatsoever in cylinders of 70" or more diameter, although fairly high steam pressure and superheat are used. There is no reason to assume the German pig iron is any better than ours and the logical conclusion is that we can develop just as much power in one cylinder as our friends across the Atlantic do, provided that there is a demand for such an engine.

When it comes to the question of the reliability of the duoflow engine of either the Corliss or poppet valve type compared to that of the unaflow engine, the latter has the advantage, because it is less complicated. It has no valves under the cylinder. All moving parts are aboveground and accessible. We all know from practical experience that parts which are so located are promptly attended to and that inaccessible parts are neglected.

It has been pointed out that duoflow engines can be made just as economical as unaflow engines. That is correct, but the great advantage of the unaflow engine lies in its sustained economy over great variation of load. An engineer who is thoroughly familiar with conditions around rolling mills and steel plants made this statement to me: "Whenever I want an engine to run at predetermined fixed load, I buy a compound engine, because it will give me the same or maybe even a slightly better economy than the unaflow engine will; but when I want an engine whose load fluctuates up and down all the time, then I buy a unaflow engine."

Replying to the question of Mr. Egan whether I use Rankin cycle efficiency in both cases with regard to brake horsepower or whether I refer to indicated horsepower, I wish to say that I use brake horsepower all through, because there is no indicated horsepower in a turbine. It has been mentioned that the steam jacketing of the unaflow engine induces a loss. The figures given include that loss, because all of the steam delivered to the engine passes through the jackets into the cylinder so that there is no possibility of steam getting anywhere else except into the engine cylinder. In making tests of unaflow engines, I have always been careful to provide a drain at the lowest place of the steam pipe so that any water contained in the cylinder heads might be collected and weighed. I have never been able to find sufficient water to make any difference in the economy.

Mr. Egan brought up the question as to whether I might not have referred Rankine cycle efficiency in one case to the back pressure and in another case to the release or terminal pressure. This was not done, because Rankine cycle efficiency is always based on the straight heat drop from steam pressure to back pressure. All efficiencies given in the paper

are based on this adiabatic heat drop. The great difference between non-condensing and condensing Rankine cycle efficiencies given in the paper is principally due to free expansion loss. In non-condensing work or on small vacuum the unaflow engine expands very close to the back pressure line so that free expansion loss is either wholly absent or is very small. The higher the vacuum, that is to say the lower the back pressure, the greater the free expansion loss must be and the lower becomes the Rankine cycle efficiency of the unaflow engine.

Mr. Egan compares the steam consumption of the turbine to that of the unaflow engine referred to in Fig. 3. This is not altogether fair, because the engine in question is only of 300 h.p. capacity and it will hardly do to compare so small an engine to a very large turbine. Unaflow engines of larger capacity work with considerably better efficiency than the mite of an engine cited here. Unfortunately we have as yet no very large unaflow engines in this country and it became necessary to give the steam consumption of the smaller engines which we have.

Mr. Wilson made reference to uniform boiler conditions and states that motor drive makes it possible to have uniform boiler house conditions. Uniform boiler house conditions may be very desirable in connection with steam turbine drive, but it has never entered my head why a constant steam pressure should be striven for in steel works practice. Boilers are equipped with damper regulators and stoker regulators for the purpose of maintaining a constant boiler pressure. In my opinion, such apparatus is superfluous in a steel plant boiler house. Why do we not buy boilers strong enough to stand 250 pounds per square inch pressure and then run them at an average pressure of approximately 175 pounds per square inch? If we allow the pressure to run up and down with the demand for steam, then we obtain quite an advantage. If several engines are shut down waiting for steel, let the pressure rise. When the engines are started up again, taking lots of steam, let the stored-up pressure be used for developing more steam. On the other hand, the maintaining of uniform pressure means that stopping of the engine necessitates closing of dampers and slowing down of the stokers; then when the engines take up

their work again, the boiler is in no condition to furnish the additional steam. In my opinion variable boiler pressure is more desirable in the steel mill than constant boiler pressure.

F. D. Egan: In my comparison of the small engine the Professor refers to, I was not making a comparison of the engine as a prime-mover in a power plant, but rather as applied to mill drive. We will take anything on mill drive from a fraction of a horsepower to an unlimited capacity in the motor drive. The comparison I was making was the installation of an engine driving a mill versus a motor driving a mill, and the information we had at hand was that given by Prof. Trinks in his paper. There are now a number of these engines being installed, so that we may all have the information that he has gained from the tests conducted at the Carnegie School of Technology.

There is one thing in the discussion which the Professor has not directly referred to, but he did refer to it in a sort of way, in the matter of the use of the engine in the power plant. It is well known by the gas engineer that we can produce a kilowatt for one-half the heat value required in a turbine unit, so when you want to talk about heat efficiency we must go back to the gas-engine power plant in connection with motors or mill drives.

J. H. Wilson: Prof. Trinks understood my remarks about uniform power load to refer to boiler pressure. I did not refer to steam pressure at the boiler house, but to the rate of steam on the boilers. In other words, the more uniform the demand for steam on any boiler house, the better efficiency is possible. As there is a large variation in the number of pounds of steam required from the boiler house per minute or per hour, the boilers work at various percentages of capacity, and, therefore, the various degrees of efficiency.

By taking advantage of the fly-wheel, motor control, and other equipment to steady the mill loads, the practice can be kept such in the boiler house, and the correct number of boilers to get the necessary efficiency can be operated under the best of operating conditions.

Fred. B. Crosby: Although the discussion of Prof. Trinks has dealt chiefly with problems of thermo-

dynamics, reference has been made to the possibility of operating the unaflow engine at reduced speed without serious reduction in efficiency. A few years ago this characteristic might have had great weight in determining a choice between engine and motor drive. The problem of an efficient adjustable speed control for alternating current induction motors has, however, been successfully solved and for Prof. Trink's information I would state that within the past three years, we have built and have on order, an aggregate of 50,000 h.p. of normal-rated motors, for which we have provided adjustable speed control. I should be very glad to discuss further details of this system of speed control with any interested party.

G. E. Stoltz: There is one question I would like to ask. My experience with steam engines has been in testing old engines that have been in service for some time, and the values of economy we get in those cases are widely different from the ones given in this paper when the usual guarantees are made. I was wondering how long we can expect these test guarantees to hold good after the engine has been in service; after it is in service, its horsepower does not suffer but its economy usually does.

In discussing the economy of the turbine with the engine, we are only discussing a small portion of the proposition. The question comes up as to whether a mill should be electric or engine driven, and to answer that question we have to consider everything back to the coal pile in every case, and not discuss the particular economy of the engine.

W. Trinks: In answer to Mr. Egan's discussion I wish to say that I would never install a 300 h.p. engine in a mill. I think that there is a lower limit for these engines and I should place it off-hand, without much thinking, at about 750 to 1000 h.p.

Coming back to Mr. Wilson's remarks, he either misunderstood me or I misunderstood him. I did not propose to maintain a uniform pressure in the boiler house, but I propose to maintain constant rate of heat transmission through the boiler shell. If that rate is kept constant and no steam is taken out, temperature and pressure will rise. My proposition is to let this pressure rise occur and to use the excess pressure as soon as there exists a demand for it.

work again, the boiler is in no condition to furnish the normal steam. In my opinion variable boiler pressure is more desirable in the steel mill than constant boiler pressure.

F. D. Egan: In my comparison of the small engine the Professor refers to, I was not making a comparison of the engine as a prime-mover in a power plant, but rather as a motor drive. We will take anything on mill drive as a fraction of a horsepower to an unlimited capacity in motor drive. The comparison I was making was the indication of an engine driving a mill versus a motor driving a mill, and the information we had at hand was that given by Prof. Trink's in his paper. There are now a number of engines being installed, so that we may all have the information that he has gained from the tests conducted at the Carnegie School of Technology.

There is one thing in the discussion which the Professor has not directly referred to, but he did refer to it in a general way, in the matter of the use of the engine in the power plant. It is well known by the gas engineer that we require a kilowatt for one-half the heat value required for a steam-bine unit, so when you want to talk about heat efficiency we must go back to the gas-engine power plant and compare it with motors or mill drives.

F. H. Wilson: Prof. Trink understood my remark as referring to a uniform power load to refer to boiler pressure. I refer to steam pressure at the boiler house, but not to the variation of steam on the boilers. In other words, the more uniform the demand for steam on any boiler house, the more efficiency is possible. As there is a large variation in the number of pounds of steam required from the boiler from minute to minute or per hour, the boilers work at various percentages of capacity, and, therefore, the various degrees of efficiency.

By taking advantage of the fly-wheel, motor and other equipment to steady the mill loads, the variation is kept such in the boiler house, and the correct use of boilers to get the necessary efficiency can be obtained under the best of operating conditions.

Fred. B. Crosby: Although the discussion in the Professor's paper has dealt chiefly with problems of

If that is done, no fly-wheel set is needed for making boiler-house conditions uniform.

The losses of heat in steam lines have been mentioned repeatedly, and in connection therewith I agree with the spakers that it would be foolish to install any steam engine, whether duoflow or unaflow, or with any type of valve gear, at the end of a long steam line. On the other hand, one feature exists in connection with steel plants which has not yet been brought out, and that is the fact that rising fuel prices compel us to use waste-heat boilers on open-hearth furnaces. The use of such boilers started at the South Chicago Works of the Illinois Steel Company and is spreading rapidly.

This use of waste-heat boilers in connection with open-hearth furnaces takes the ground away from under one of the biggest arguments which the electrical engineer has for centralization; namely, that he can put his power plant where it is most convenient for fuel supply and for supply of condensing water. If one of the principal boiler plants is located directly at the open-hearth furnaces, the power plant must either be located right there, or else it must put up with just as long steam lines as the engine does if it is located elsewhere. As a rule it will not be very desirable to have the power plant located in the immediate neighborhood of the open-hearth furnaces, and in that case the use of engines may well be considered.

Above all, I do not wish to be misunderstood as stating that the unaflow engine is a cure-all for all ills that can befall engines. About eight years ago the low pressure steam turbine was considered the cure-all for all power plant evils and it suffered by having its importance overestimated. No such fate should befall the unaflow engine. But what I contend is that there are many conditions under which the unaflow engine will save money to the stockholders and that is all engineers should consider, no matter whether they are electrical engineers or mechanical engineers.

The question was raised, how long the economy of the unaflow engine may be maintained without depreciation. In this respect the unaflow engine is far ahead of other engines. The piston is the exhaust valve. It is equipped with a sufficient number of rings to make leakage improbable. The

inlet valves are usually of the poppet valve type. As soon as they begin to leak, the compression, or the apparent compression, rises by leaps and bounds. Any steam which leaks into the cylinder during the early part of compression builds up the compression so rapidly that it rises away above the steam inlet pressure. The steam inlet valves are on purpose made sufficiently unbalanced to rise under this pressure, and in consequence the valves begin to clatter and be noisy to such an extent that the engineer is warned in time to regrind the valves. In duoflow engines no such warning is given, because steam leaking through the inlet valve can pass directly into the open exhaust.

J. H. Wilson: In reply to Prof. Trinks' last statement I desire to make my remarks clear.

We will consider a blooming mill which is engine-driven. The mill shuts down due to lack of steel or due to some other cause. Later, the mill is ready to start. If this mill is engine-driven the maximum demand upon it will be 10,000 or 15,000 h.p. If the mill is motor driven, even though the maximum demand would be 10,000 or 15,000 h.p., the power which would have to be put into the fly-wheel motor generator set would only be 2000 or 3000 h.p., resulting in a much smaller increase in steam load.

Of course the fly-wheel energy does not hold over from one hour to another, but the operating characteristics are such as to require a fluctuating amount of steam in the case of engine drive, and in the case of motor or fly-wheel properly designed and controlled it would require a uniform supply of steam.

W. Trinks: Answering Mr. Wilson, I wish to confine myself to a discussion of the unaflow engine. I did not anticipate that the discussion would take up the question whether engines should be used in a mill at all, or whether they should be replaced by electric motors. Unaflow engines have not yet been built of the reversing type. The question of whether reversing engines or reversing motors should be used is one which is of great interest to me, but which I prefer not to discuss at the present meeting.

UNDERGROUND DISTRIBUTION SYSTEMS

By G. J. NEWTON

The following facts and suggestions are based on many years experience with underground distribution systems, and are stated in the following article with the intention of showing the importance of careful and intelligent design as related, not only to the first cost, but to the economical operation and ultimate value of the completed system.

An inspection of many systems has made it evident to the writer that improper design is responsible for more faults than is poor construction, and it is with a sincere desire to aid others interested in this work, to avoid such mistakes in the future, that these suggestions are offered.

No two systems are entirely alike, and the conditions are different in every place; it is, therefore, impossible to formulate any definite rules that will apply under all conditions. The engineer must be guided by good judgment, based on experience, and a thorough study of the conditions in order to secure satisfactory results.

Owing to the increasing demand for electrical energy, and the serious objection to the unsightly and dangerous overhead wires and poles, underground systems of distribution have become a necessity in many places where the expense of this class of service would not have been considered warranted under former conditions.

Underground distribution is very expensive, as compared with overhead construction, and in many cases, particularly in the smaller cities, the first cost is of vital importance; a carefully worked out design is therefore necessary in order to derive the greatest benefit from the money expended. Many of the present systems have not been designed with the care, and attention to detail, that their import-

ance deserves and frequently the cost of the system has been entirely out of proportion to its ultimate value.

The first installation of an underground system is made necessary by an order of the city authorities compelling the removal of poles and wires from certain sections of the city or by the desire of the operating company to improve the service and secure greater facilities in a district where the demand for light and power has reached a point that this class of service is warranted.

In either of the above cases, and in fact, practically in all cases in this country, underground systems are never installed until long after the district has been supplied by an overhead system. As a general rule, all overhead systems are the result of a series of extensions and changes, rather than the development of any systematic plan of distribution, and are seldom based on efficient or economical methods.

If it were possible to design and install an underground system at the start of an electrical undertaking the problem would be much simplified, as the station and consumers equipment could be selected, and the whole system designed for the most efficient results. Unfortunately the conditions are never so favorable, and the distribution engineer is confronted with many conditions over which he has no control, but must consider in making his plans.

Distribution problems are, therefore, usually very complex and permit of several methods of being solved. It is only by a careful study of the conditions and foresight as to the future requirements of the system that a satisfactory, economical and efficient design can be developed.

The conditions under which underground cables and equipment operate are more severe than on overhead systems, and a thorough knowledge of these conditions is absolutely necessary, and must be kept in mind, in selecting cables and equipment and designing the conduit system for their installation. Overhead wires can be, and frequently are, operated far above their rated capacity, without any serious danger, but underground cables and equipment must be operated within certain definite limits in order to avoid serious damage, if not total destruction.

Economy of distribution is equally as important as economy in production, particularly at the present time, when practically all public utility companies are regulated, to a greater or less extent, by state or municipal commissions. First cost is not, therefore the only factor that should be considered, as economical operation and reliability of service are equally as important in the financial success and growth of the business.

Except in the large companies, there is probably no branch of the business that has been given less thought and study than underground work; in many cases the principal object evidently has been to get the wires out of sight at the least possible expense, with no attempt being made to improve the system of distribution and little or no regard for the future development of this class of service.

The operation of an underground system when properly designed, installed, and maintained guarantees the most reliable and efficient service of any method of distribution ever employed; the financial benefit, directly due to this class of service is in many cases, a proof of the wisdom of its installation.

While it is admitted that underground systems are expensive to install, still it must be remembered that a conduit system is a permanent structure, has little or no depreciation; on the contrary it will increase in value as the importance of the section it serves is developed. Considering the first cost, permanent nature of the undertaking and importance of economical and reliable service, it is advisable to make a thorough study of the conditions and future requirements of the service on which to base a design of the proposed system.

In designing an underground distribution system there is one important fact that must always be considered—the system should be designed to serve the entire district that can reasonably be expected to ever require this class of service. Such a design permits of a systematic scheme being developed for the whole district, uniform methods of construction, and standardization of equipment.

If this method is followed it is then possible to install any section, from time to time as the service demands, and each completed section will form a part of the whole general

scheme and eventually develop into a system rather than a collection of more or less useful sections of conduit.

It is not the object of this article to show each step in the design of any particular system but rather to point out certain important features to be kept in mind and offer suggestions as to the general method to be adopted; it is only by a thorough study of each case that the best methods can be determined.

The first step in designing an underground distribution system is to secure an accurate load record for each consumer in proposed underground district. The record should be

<i>135 Washington Street</i>										No.	
<i>William Henderson & Co.</i>										VOLTS 110 - 220	
LIGHTING LOAD											
SIZE		10	25	40	50	60	80	100			WATTS
LIGHTING			40		20	110					8600
SIGN		90						5			1400
APPLIANCES											
<i>10 Desk Fans</i>										660	
<i>3 Irons</i>										300	
TOTAL LIGHTING LOAD										10960	
POWER											
<i>2 - 5 HP 220 Volt 3ϕ Motors</i>										10000	
<i>1 - 10 HP 220 Volt 3ϕ Motor</i>										10000	
TOTAL POWER LOAD										20 Kw.	
L SERVICE 105 ft #4 - 3 Conductor						TRANSFORMER 14 A					
P SERVICE 110 ft #4 - 3 Conductor						TRANSFORMER 14 A - B - C.					

Fig. 1

kept on cards similar to Fig. 1; where there is a large power load in the district it is advisable to make separate records for the lighting and power loads, using different colored cards for each record.

The card shown in Fig. 1 is simply a sample, and the best arrangement of the inventory on the cards will depend on the requirements of each particular system.

The reverse side of the cards can be used for showing the number and location of the transformer supplying the service lateral, consumers fuse box and other information connected with each consumers service.

These cards if properly corrected will form a perman-

ent record of great value in making future changes and balancing the load on the distribution system.

The men securing the load record should be provided with paper pads printed the same as the cards and the permanent card record can be made in the office from these slips and the cards be kept clean and neat.

A careful inspection should be made of each building to determine the most suitable location for the new underground lateral in order to reduce the cost of changing the inside wiring as much as possible. Except in the case of very heavy loads or consumers where emergency service must be provided for, it is advisable to supply all of the consumers in a building from one lighting and one power lateral, this reduces the number of laterals, handholes, and fuse boxes and permits using the least amount of copper by taking advantage of the diversity of a group of consumers.

The lighting and power load can be plotted on one drawing as shown in Fig. 2 or the loads can be plotted on separate plans, the latter method is best as the plans for each system can then be kept separate.

The load maps for each system should show the total load, both in the underground district and outside of it, that is to be supplied by cables in the conduit system from the power house so that ample conduit space can be provided and the most suitable routes and sizes of feeders determined.

Having the lighting and power loads and a map showing the street light system, the next step is to determine the most suitable plan of distribution to be adopted, this may be called the critical point in the design of a distribution system, for on the decision depends not only the first cost of the installation but the reliable, efficient and economical operation of the distribution system.

There are two general schemes of distribution:

1. To supply the whole city from one power house.
2. Divide the city into districts and supply each from substations, or rather from the power house and substations.

In many of the older systems the first method was used and a large number of ducts were installed, in one trench from the power house, to serve the whole city, or at least that portion that was to be supplied by underground eventually. This necessitated providing a large number of spare



Fig. 2

ducts, a large percentage of which remained idle for years and not infrequently resulted in too many ducts in some places and too few in others.

Not only was the first cost of such a system excessive but the manholes were almost invariably too small to accommodate the number of cables that could have been installed in all of the ducts had there ever been use for them. The most serious objection to this plan is that the losses due to the heating of so many cables in one conduit run are excessive and materially reduced the carrying capacity of the cables, particularly in cables occupying the inner ducts.

Another serious objection to this method is that a burn-out on one cable is practically certain to damage adjacent cables and cause interruption of service over a considerable area. Faults on underground systems usually affect more consumers than on an overhead system and require more time to repair, therefore, no system should be considered that does not permit being sectionalized and have reasonable emergency facilities provided for restoring service with the least possible delay.

The objection to the first plan, as stated above, preclude its adoption except in very small cities where the area to be served by underground distribution is limited, and the total number of ducts installed in one trench will not be excessive.

The second method of distribution, when properly designed, avoids all of the objectionable features of the first method and is particularly adapted to the modern practice of installing sub-stations supplied by high-tension feeders, as each district is practically operated separate from the others and with suitable emergency feeders and switching equipment permits each district to assist the others in case of necessity.

The old saying "That you should not put all of your eggs in one basket" is particularly true if we change the words slightly—"You should not put all of your feeders in one trench or manhole" and the distribution engineer will be wise to keep this warning in mind as far as the requirements of the case will permit.

Reliable service and economical distribution are absolutely necessary for the financial success of every light and

power company. Reliability depends on the following conditions:

1. The best material, equipment and workmanship.
2. Proper selection of material and equipment for the service it is to supply.
3. Efficient protective apparatus, judiciously installed.
4. Sectionalizing apparatus properly located.
5. Continuity of supply, by feeders over different routes or an arrangement that will provide at least two sources of supply for the network.
6. Regular and systematic inspection of the distribution system by competent men.
7. Accurate plans and records of the distribution system so that changes, additions and extensions can be made to the best advantage with the least possibility of error.

Economical operation depends upon a reasonable first cost, in addition to all of the above conditions, and where a system is designed at first for a whole city (keeping in mind future sub-stations) it is possible to reduce the number of ducts and manholes to a minimum, install sections as the business warrants and extend the ultimate cost over a considerable period.

Keeping the above facts in mind the actual design of an underground distribution system should be made on the following general plan. Assuming that the first underground installation is to supply a district similar to that shown in Fig. 2, and that later this district will be extended a block or two in each direction and supplied from the main station.

While it is admitted that it is not possible accurately to foretell where substations will be located in the future, still a study of the conditions will generally permit a reasonable assumption to be made and if separate conduit is to be installed later for high-tension feeders this part of the work does not enter into the first design except in a general way.

After making the load maps for the lighting and power systems and also a map showing the location of the street lights it is a good plan to first lay out the street light circuits, for assuming that all wires in the district must be placed underground it is evident that conduit must be installed to reach every light.

The location of the street lights is determined by the city authorities and can seldom be altered enough to materially change the conduit arrangement, therefore, by designing this system first it will give a general idea of where the conduit **must** be installed and keeping this plan in mind it is frequently possible to arrange the secondary mains so as to utilize the same routes (particularly in alleys and the less important streets) so as to avoid considerable conduit construction.

The proposed location of the laterals in each building should be shown on the plan for the secondary systems for light and power. A study of these locations together with the street light conduit layout will often show where slight changes in one or the other will permit considerable saving, even when changing some laterals will increase the cost of the inside wiring.

Owing to the fact that the grouping of consumers, in a district, will usually be different on an underground system than it was on the original overhead system it is practically impossible accurately to determine what the demand and diversity factors will be for the new system. A distribution system for either lighting or power usually consists of the following sub-divisions:

- Primary feeders to centers of distribution.

- Secondary feeders supplying the transformers.

- Secondary mains supplying the service laterals.

- Service laterals supplying the consumers.

In small systems the secondary feeders are not required, as the transformers are connected directly to the primary feeders.

The size of cables to use for the laterals is easily determined, the principal object is to restrict the number of sizes of cable as much as possible, using about three sizes for the whole system, and if possible, making the largest size used for laterals the same as one of the sizes used for secondary mains.

Aside from the laterals it is evident that the secondary mains receive less benefit from the diversity factor than any other part of the system. It is also evident that any increase in the load will directly affect the mains which must

be large enough to maintain satisfactory voltage for all consumers connected to them.

On the one hand is the diversity factor tending to reduce the size of the mains and on the other hand the probable increase in load which must be provided for, tending to increase the size of the mains. As not only the first cost but the interest on the investment depends on the size of the copper, it is important that these two conditions be given careful consideration and it is in cases of this kind that the engineer must be guided by experience and his knowledge of the situation.

There is one point that should be remembered in determining the size of cable to install for secondary mains, particularly where they serve a number of consumers in a business district. Owing to the fact that the service laterals are spliced directly to the mains at frequent intervals it is very expensive to replace them and the old cable, being in short lengths, is of little or no use except for its junk value; it is therefore advisable to make all secondary mains of ample size to provide for the total load that can reasonably be expected and use the best kind of cable, either varnished cambric or rubber insulated, for all secondary mains and laterals that terminate in junction or fuse boxes.

The load in the district should be divided as equally as possible into a suitable number of distribution centers so that one size and style of cable can be used for all of the feeders, as this permits standardizing the equipment and requires less cable being kept in stock for emergency purposes.

The feeders being generally small cable and having few or no taps on them can easily be replaced by larger cable and the old cable is in sufficient lengths to be used elsewhere. Instead of installing a larger cable to replace a loaded one it is generally better to install an additional feeder to another center of distribution, using the standard size of cable.

Where the requirements of the system demand the use of two-conductor cable it is advisable to have it made up in round form instead of the flat, or figure 8 style, as it is practically impossible to train this latter style without kinking it.

A careful study of the conditions under which under-distribution systems operate, particularly in medium

size or smaller cities, has convinced the writer that the safest guarantee of reliable, efficient, and economical operation is to install cable and equipment, as far as the conditions will permit, under the following general rules:

Service Laterals. Use either cambric or rubber insulated cable, spliced directly to the secondary mains, and terminated in water-tight fuse boxes on the consumers property. (The number of laterals taken out at one splice will depend on the system; for single-conductor cables four laterals can be taken out, but two is about the limit where three conductor mains and laterals are used.)

Secondary Mains. Make these cables of ample size to provide for all the growth that can reasonably be expected. Use either varnished cambric or rubber insulated cable for all secondary work where cables terminate in subway equipment.

Primary Feeders. These cables derive the most benefit from the diversity factor, are comparatively long lengths, and have few taps on them, therefore are less subject to damage than the rest of the cables and are easily replaced with small financial loss. Small reserve capacity is all that need be provided for this class of cables.

Paper insulated cable can be used to advantage frequently at considerable saving providing that the ends are properly terminated in compound-filled potheads or varnished cambric or rubber insulated tails used for connecting to the equipment.

Personally, the writer does not approve of using any paper insulated cable on distribution systems, except on cases where the emergency facilities are such that the failure of a feeder cannot cause a serious interruption to the service.

In small companies, where competent cable men are not always available, the use of paper insulated cable on the distribution system is not advisable, it is however, well suited for high-tension feeders and tie-lines.

Subway Equipment. Due to the liability of being submerged occasionally and the limited space usually available, for its installation, subway equipment is probably the most prolific cause of trouble on underground distribution sys-

tems, and the greatest care must be used in selecting and installing it.

The best insurance against trouble from this cause is to provide reliable sewer connections to all manholes and vaults in which subway equipment is located. Separate the primary and secondary equipment by placing the transformers, primary fuses and switches in a vault (preferably located under the sidewalk adjacent to the manhole in which the secondary junction boxes are located.) This arrangement reduces the length of the secondary mains, which are usually large expensive cables, and lessens the liability of a burnout of the primary equipment damaging the secondary network. See Fig. 3.

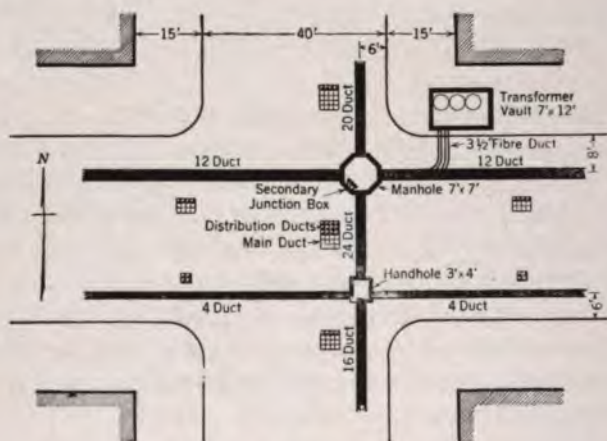


Fig. 3

The object in placing the vaults under the sidewalk is that it is seldom possible to secure sufficient room in the street also there is less liability of the vaults being flooded from surface water and they are more accessible in the winter when the ground is covered with ice and snow. This method of construction is more expensive than placing all of the equipment in the manholes but the added security is well worth the expense on an important installation.

Subway transformers should not be set on the floor of the vault but should be raised so that the air can circulate under and around them. Where more than 200 kw. of transformer capacity has to be installed in one vault it is

advisable to provide ventilating pipes from the vault to a pole or side of a nearby building.

Subway junction and fuse boxes should not have slate or marble bases, but use ebonite or similar material that will not absorb moisture. All boxes should be subjected to an insulation test before being installed. Barriers should be provided between terminals of opposite polarity.

The iron work of all subway equipment should be permanently grounded to a reliable ground rod, plate, or if possible, to the city water pipe system. In large vaults, where there is considerable equipment, at least two ground connections should be provided.

Installing Cable. Assuming that all cable has passed the usual factory test, it is seldom necessary to subject it to another test before being installed unless there is some evidence that it has been damaged in transit. The conditions under which the cable is purchased and installed will, however, generally decide this point.

Use skids in loading and unloading reels, never drop them off of the truck. Place reels as near the point where they are to be used as possible. When reels must be left on the street for some time they should be securely blocked or preferably wired to a bolt to prevent their being rolled about. Care should be taken not to place reels where they will interfere with hydrants, or obstruct manholes, water gates or traffic.

Never handle paper insulated cable when it is cold. In cold weather it should be kept in a warm place until it is to be installed. Paper cable should not be bent shorter than eight times its diameter and should be warmed before bending.

Always provide sufficient men and power to safely handle cable during installation, when the cable is started in the conduit try to maintain an even steady rate of pulling. For heavy cable it is advisable to use grease or powdered soapstone.

Ends of cables should be kept sealed until ready to be spliced. Cables should not be left hanging from the duct mouth, but should be supported on hangers with as little bending as possible. The final bending and training of the

cables should be done by the splicer when joining the sections.

When installing a new system, all lengths of cable should be bonded together temporarily as soon as they are installed. As soon as the cable system is completely connected up tests for electrolysis should be made of the whole system and proper measures taken to protect the cables in case of necessity.

The arrangement of cables and equipment in the man-holes and vaults must be carefully planned to secure neatness and ample space in which to work and operate the equipment with safety.

All cables and equipment should be plainly marked showing the operating voltage and system it is used for. Where single conductor cables are used on three phase circuits they should be distinguished by different colors as this will prevent mistakes in making changes as only cables of like colors should be connected together.

While it is admitted that it is impossible to install a system that will be entirely free from trouble, it is possible by carefully designing the system to prevent many of the faults that are a constant source of trouble on many systems.

Conduit System. The conduit system should be designed to serve the electrical distribution system as previously designed. This statement may, at first, appear to be a self evident fact, but unfortunately many conduit systems are not arranged to properly, and economically provide facilities for installing the proposed cable system. It is not an uncommon practice to install a conduit system based on a general assumption of the actual requirements of the electrical system.

The writer has seen conduit systems in which it was absolutely impossible to install the distribution system as it had to be operated, and which had to be partially rebuilt before the cables and equipment could be installed. These are no doubt exceptional cases but it shows the importance of a definite method of procedure in designing an underground distribution system.

It is a common practice in designing conduit systems to select streets or alleys having the cheapest pavement in

which to locate the conduit, and then attempt to fit the electrical distribution to this location, and the result is invariably unsatisfactory and the saving in the cost in repaving is frequently exceeded by the additional cost of cables, and the total cost of the system thus increased.

It should be realized that a properly designed and constructed conduit system is a valuable property, and a permanent structure having little or no depreciation, and its importance in the supply of electrical energy warrants the greatest care being taken in its design and construction.

Conduit systems that are to serve high-tension or tie-lines between substations can be located so as to avoid the more expensive pavements, but conduit used exclusively for distribution systems should be located so as to best serve the electrical requirements regardless of the kind of pavement on the streets or alleys.

In a conduit system used exclusively for distribution (where all wires must be placed underground) the best location is usually in the streets. In cities having an alley in each block there is strong tendency to locate the conduit in the alley.

The desire to utilize the alleys is based on the fact that the pavement is usually less expensive, and as the majority of pole lines are in the alleys the buildings are supplied from the rear, therefore if the conduit is located in the alley there will be less expense of changing the inside wiring to meet the new distribution system. At first sight these advantages appear so great as to warrant the selection of the alley; there are, however, serious disadvantages to this location.

The alleys are usually from 16 to 20 feet wide and are generally fairly well occupied by water, gas and sewer facilities, and not infrequently, by one or two telephone conduit systems (which are usually installed before the electric light wires are placed underground) and the space available is, therefore, very limited.

The rear building line is very irregular, many buildings do not extend back to the alley, and frequently there are small sheds or extensions in the rear of the main buildings. The length of rear laterals would be greater than front ones and the difficulties and cost of installation considerably more; the *greatest objection* is that the rear laterals would

not be permanent in many places but would have to be changed whenever any new building construction or changes were made.

Where alleys are located in the business section of a city they are usually used by the merchants for receiving and shipping goods and are subjected to a heavy traffic, considering the limited space. The merchants are practically all consumers of electric power and will strongly resent any interruption to their trucking facilities.

Owing to the limited space in the alleys, and the amount of traffic, it is practically impossible to store any material in them, consequently all material used on the conduit system must be stored in the adjacent streets and usually wheeled in by hand. This work and the excavation for manholes, removal of surplus material, etc., will practically close the alley to traffic and the inconvenience of doing the work will greatly increase the cost of construction.

There is another serious objection to using the alleys. An average block, in cities having alleys, is about 300 by 300 ft. (91 by 91 m.) and usually has at least twelve separate buildings in it, in the business section there are generally more. When the distribution system is located in the alleys all of the buildings in a block are supplied from one secondary main which practically doubles its size, and the number of laterals that must be connected to it require frequent handholes in order to reduce the length of the laterals. This entails more complicated and expensive splices, cuts the main into short lengths, and in case of serious trouble puts the whole block out of service.

As a general rule, with the single exception of requiring less conduit, the alley construction is less desirable than a system installed in the streets. This statement applies to the business district of a city. Where overhead laterals can be used in a residential section the alleys are preferable for the location of the conduit, and as the traffic and obstructions are usually considerably less in such sections, the construction cost will be correspondingly less, depending on the pavement.

Before making the conduit design it is necessary to plot the location of all car tracks and existing sub-surface obstructions, in order to determine the most suitable location

for the new system. While it is known that the records of sub-surface conditions are seldom accurate still a study of these records and the location of water gates, sewer man-holes and other surface indications will permit a fairly accurate map may be prepared.

Where there is any doubt regarding space being available for the conduit and manholes it is advisable to dig test holes, and if possible they should be dug at the points where it is proposed to locate manholes.

The design of an underground distribution system is not a difficult matter if handled in a systematic manner and the result obtained from a thorough study of the conditions will fully warrant the engineering expense necessary to prepare accurate plans covering every detail of the work.

DISCUSSION

T. E. Tynes: This most excellent paper, prepared by Mr. Newton, and so very ably presented by Mr. Gear, covers the question of underground distribution of energy in a very broad way. Mr. Newton has given a great deal of time and thought to this question of underground distribution, and while the paper applies particularly to the distribution of energy in cities and congested districts, such as we have here in Chicago and in other large cities, the principles involved are applicable to any underground system which we may have occasion to use in steel mills, such as the construction of conduits, the making of joints, the position of switches, etc., and I hope we may have a very free discussion of this subject this morning.

Alfred F. Hovey: A great deal of time might well be given to the discussion of this paper as regards the detailed construction of the conduits and cables. There is one point which involves a rather dangerous point; the author states: "Where triplex conductor cables are used on three-phase circuits, they should be distinguished by different colors as this will prevent mistakes in making changes as only conductors of like colors should be connected togeth-

er." I have personally encountered a good deal of difficulty from just that kind of a specification. It is almost next to impossible to make joints that will be serviceable for a long term of years, such as good joints do, and at the same time secure the matching of colors. The time has come when we are using large conductors in sector form, and under those circumstances it is still more difficult to match these colors. Very often it requires one of the conductors to be drawn through and between the other two conductors in order to match the same color, and there is no safe way of identifying the conductor and be sure you are right, except by making a test one way or another, without possible damage to the insulation. Jointers find they cannot make as good a joint where they attempt to match the colors. The cable has to be manufactured in a certain way, so that the lay is all one way, and the cable has to be pulled in, in a certain direction, and sometimes it is impossible to feed the cable into one of the manholes, but can be pulled by means of a series of blocks and tackles, but if the cable is not drawn in exactly right, it is extremely difficult to straighten out the lay of the conductors at the joint, so to match the conductors although it sometimes happens; but then it is a matter of chance. That is one point which I think it might be well for engineers to avoid in making up specifications to secure a perfectly satisfactory operating system.

Another point where the writer of the paper says: "Personally, the writer does not approve of using any paper-insulated cable on the distribution systems, except in cases where the emergency facilities are such that the failure of a feeder cannot cause a serious interruption to the service." Several managers of works with which I am concerned at the present time, are installing paper-insulated cables both for economy and for good operation. A paper-insulated cable requires slightly more careful installation, but if properly handled, I believe in many cases that it will make as good insulation as either the rubber or varnished cloth insulation. It has been my experience that recently the majority of engineers specify paper cable. There is no particular reason for bringing up that point, as nearly all cable manufacturers are prepared to furnish either rubber or varnished cloth or paper insulation on their cables.

Just want to add a word of commendation to Mr. Newton, who has had considerable experience along this line for years. We have known him, particularly in conduit-work, and in cable-work for years, and I believe that this paper will be of great assistance to engineers in laying out either a large or small system, because it gives the basis in foundation of fact for a specification that would provide a satisfactory operating system.

Not having read this paper carefully enough to know whether any mention is made of a scheme used considerably nowadays, that is to run the trunk ducts underneath the service boxes, would state that this is an important feature in designing space for trunk feeders and secondary mains by building a handhole over the top of the lower trunk conduits and taking in only the top ducts, using them for distributing mains and secondary feeders. That is a point on a small system that is particularly important, as it cuts down the original cost of the conduit system materially. In that way, the small conductors can be exposed through these handholes for taps and the handholes can be constructed at very small cost and at large insurance over the other scheme of opening all the ducts into all the man-holes.

There is one man-hole that has cost, as I was informed last week, about \$10,000, because the engineers originally did not make the man-hole large enough. The man-hole has been rebuilt eleven times, with the consequent cutting of cables and re-racking them around this constantly enlarged man-hole. One of the operating engineers told me not long ago that his company was expending over \$150,000 a year rebuilding man-holes. That is a point that the engineer, in laying out an underground distribution, might well keep in mind, because it is well known that the cheapest real estate is that which you enclose by a man-hole wall under the street. By making a large, generous man-hole, you have plenty of racking space for the cables on the sides, with sufficient room on the side-walls for proper racking and proper bending, and the original installation will take care of the operation in the future much better than having to rebuild the man-hole at considerable extra cost.

F. D. Egan: My experience with underground conduit work has been entirely in the steel plant, and I could not

discuss Mr. Newton's paper from the standpoint of city construction. We have installed approximately 125,000 feet of underground conduits in our steel mill, and as far as the matter of trouble goes, I find that the underground system is more reliable and more dependable than the overhead system.

Another point that Mr. Newton brought up regards the high cost of underground versus overhead. While that might apply in city construction, if compared to the type of construction to be used in a steel mill, the cost is in favor of the underground. When we distribute power at 6600 volts, or higher, for safety reasons we would construct duplicate power lines and the cost of this would be higher using bare copper pole lines than it would be with underground system and lead-covered cambric cable.

That is the experience we met with in our construction. We have been operating on this system in some of our plants for from three to four years, and so far we have experienced no trouble from an electrical standpoint. We lost two cables adjacent to the power house, which ran parallel with the old buildings, and the trouble there arose from the discharge of steam traps; this heat entered the conduit system, raised the temperature and the additional electrical load caused a breakdown. After we removed the steam trap discharge, we experienced no more trouble.

Another advantage of the underground system is the point of safety. We have there the point of totally enclosing the electrical distribution line, and the one point which would come up there, regarding safety, would be care in determining the proper line to work on in case of opening up of the cable.

S. C. Coey: Mr. Newton has given us a very interesting description of the methods used in laying out an underground cable system for a city and has pointed out many of the valuable features of such an installation. While many of the fundamental principles are the same, when we apply this data to an industrial plant system and especially a steel plant installation in which most of our members are most interested, we have a special application which calls for special treatment.

Installations in steel plants are more analogous to subway equipment than to any other type considered in the paper. The liability of having underground ducts filled with water is always present in those steel plants built on the banks of rivers having a large rise during flood periods. This applies to most of the plants in the Pittsburgh and Youngstown districts. Where plants are installed under these conditions it is usual to make the yard level only a few feet above the maximum high water. This is done from practical considerations as every increased foot that the plant is above normal water level means that many more foot pounds of energy expended in pumping the large amount of water necessary in the modern steel plant. This condition makes it necessary to lay out a duct system with the idea in mind that the cables are subject to the liability of being under water at some time. In plants of this description the use of underground transmission even with varnished cambric lead covered cables is subject to possibilities of trouble that are serious and makes the advisability of installing it very questionable.

In transmitting alternating current in lead covered cables it is advisable to confine all three phases within one lead sheath. When single conductor lead covered wires are used for this work there is considerable loss and possibility of trouble from sheath currents. If the sheaths are bonded the I^2R loss from the sheath currents amounts to about half the normal I^2R loss in the copper conductors so that this method of operating is inherently inefficient. As it is usually impractical to insulate all the cables from one another and impossible where flood conditions are to be met the three conductor cables should be used. In this case we have all the heating effect confined within one sheath and cable ducts must be carefully watched to see that there are not points where they get excess heating from external points.

I have also pointed out in a previous paper before this Association (Annual Meeting '14) that where grouped ducts are used, the heating effect from a center duct to adjacent outside ducts with only radiation to take care of heat dissipation is cumulative, as shown by the result of tests, and

for this reason ducts should not be made more than two ducts wide.

In underground ducts around steel mills as I have noted before it is often found that the ducts are heated from some external source. This is usually when the duct passes close to heating furnaces of some kind, which are impossible to get away from entirely in this class of work. This type of service calls for special study in each case. In some cases forced draught through the ducts have been used with good results. I have found for this work that varnished cambric insulation is the only type that can be relied upon as the heat affects rubber very rapidly.

While an underground system is usually spoken of as the most permanent system, and is, in the ducts proper, I would raise a question when we consider the wire insulation, as air and porcelain are more permanent than paper, rubber or varnished cambric and these are the materials depended upon in the two systems respectively to maintain the insulation of the circuit.

The principal advantage gained by the underground system is the freedom from liability of trouble from: lightning, pole failure, and obstructions against wires.

In steel plants the locomotive crane problem is the most serious in the last item.

The advantages the overhead system has over the underground system are: flexibility, initial cost, wire insulation and speed of location and repair of trouble.

As I see it, both systems as used today have their drawbacks and for a steel plant installation I believe that the ideal system of transmission would be to have an open concrete duct with reinforced concrete roof, well ventilated, with insulated cables strung on porcelain insulators so arranged that an inspector could walk through the duct. This could be entirely underground where the high water mark allowed, or in some plants could be above ground and used for a line fence. This system of installation would give the advantages of both the present systems without any of the disadvantages.

T. E. Tynes: We have quite an extensive duct system, originally installed about ten years ago. Our plant is built on land that was a swamp and there is a great deal of filled-

in land. We have experienced some trouble due to the settling of the ducts. In locating a duct line, especially in steel plants, great care should be taken that this line is installed where it will not be interfered with by future construction, as it is a very difficult matter, after a duct line is installed, to have to rip it up to make room for a new mill going in, or some other consideration arising, which they consider of sufficient importance to cause the ripping up of the duct system.

The selection of a suitable foundation on which to build this duct line is very important, as I mentioned the trouble we have had due to the settling of the land. We have had some cable nearly cut off due to the settling of the ground.

The type of duct, or material out of which the duct line is constructed, is also important. In our plant we constructed every circuit of vitrified duct, and we had some difficulty with cracking joints which has allowed one thing and another from the ground to come in, and these substances have eaten off our lead coating right where the joints are. We have been troubled considerably by electrolysis, and upon taking out cable we have found pin-holes, hardly visible, and they would let water into the cable.

Another important thing is making the splice. To make a good splice you should have the joint thoroughly filled with a compound, allowing no air bubbles to be formed, as in time the air bubbles will cause deterioration of the insulation and produce a breakdown. We do not know the reason for it, but we have opened up joints and found where the air bubbles destroy the insulation, and that increases until it gets to the lead sheath and then the cable breaks down.

We use paper and lead covered cables. We have had them in operation now on 2200 volts for ten years, and have had no trouble at all with this voltage. We have had trouble on our low voltage cable due to electrolysis and improper making of the joints.

All of our 2200-volt circuits are underground, also a great deal of our 440-volt circuits and 250-volt circuits. We are now taking the 250-volt circuits and the 440-volt circuits and putting them overhead.

We feel that where an overhead line is properly constructed, good insulators, and line put up in a permanent way, that it is much better for transmitting low voltages than the underground system. There is less trouble, and what trouble we have can be seen and taken care of before the trouble is too far advanced. In the case of the 2200-volt circuits, the question of safety comes in, and we put those circuits underground for that reason.

C. A. Menk: I do not think I have very much to add to the paper. It is very interesting. What are you going to do with your present installation? You have an old plant, and if you are going to add to that, what will you adopt? The first question which comes up is: "You have gotten along for years with your overhead construction. Is it going to pay to put it underground?"

Another thing; in designing a new plant I think it will be actually necessary to know what is going to be added in twenty years from now, if placed underground, because it is hard to tell what may develop and how soon it will develop. As Mr. Tynes said, to make extended changes, it would be very expensive. Take a city like Chicago and other large cities. These cities are well established, and underground work can be put in that should be good for twenty-five years, probably fifty years, especially in the residence districts, but in the case of mill-work it looks as if one would have to look ahead and make very extensive provision for added improvements in the future.

In installing an underground system on three-phase work, will it be advisable to put in the triple conductor, or single it out and put it in, in triangle form?

In installing underground work, would you put in a conduit system large enough under the present day engineering, so that you could pull out the cables and put in larger ones, to avoid having to rebuild your man-holes? One of the speakers said that in one case the man-hole was rebuilt eighteen times. To me that looks like very poor engineering.

T. E. Tynes: In reference to Mr. Menk's question, whether to install triple conductors, or single conductors, all our underground cable is three-conductor, even the 2200 up to 500,000 c.m., and as I said before, we have had no

trouble from the insulation of the cable—it has all been joint trouble and electrolytic action on the lead sheath.

S. C. Coey: I have had some experience with an installation on which single-conductor, lead-covered cables were used on three-phase work. On investigation it was found that where the lead covers of the cables came in contact, the sheath currents made pin-holes in the lead and when moisture was present paper insulation absorbed it like blotting paper. In my opinion it is a good thing to keep away from single-conductor alternating-current transmission.

H. B. Gear: You referred to low tension, I suppose?

C. A. Menk: Yes, 440-volt circuit.

H. B. Gear: I quite agree with the suggestion that the cables carrying large current should be multiple-conductor in form. A case came to my attention just recently, in an industrial plant—not a steel mill, but a condition which is very similar—where there were thirty-two No. 00 cables that had to be carried a distance of 800 to 1000 feet from the plant to the point where the power was used, and in order to keep down the inductive drop on these circuits they had made them small, but they were all overhead, and the drop was something like 33 volts on a 220-volt system in that distance. If these cables had been placed underground and made three-conductor, with a separation of only perhaps an inch between centers, the inductive component of the drop would have been very much less and the system would have been far more satisfactory. As it was, they were unable to run any additional power at the other end of the line without stringing more copper, for which room was not available on the poles.

In general, single-conductor cables are somewhat preferable for high-tension work where the lines are used for distribution purposes, that is what Mr. Newton has called secondary feeders which are really primary distributing mains.

Where joints must be made more frequently, for connecting in transformers, it is easier to do that work on single-conductor than three-conductor, from the fact that the opposite polarities can be separated. Frequently that work has to be done on either live, or very close to live wires. In general, the cost of three-conductor cables is

sufficiently less than single conductors, to warrant their use, often at the expense, as is sometimes done in man-holes or other places where taps are made, of fanning out into three singles. If the man-hole lengths are long, say four hundred or five hundred feet, it is usually cheaper to make an extra wiped joint in the man-hole, going through with singles, in order to save the cost of extra lead that would be put in the conductors in the long cable line.

In regard to paper cables, Mr. Newton's statement about paper cables is very well considered. He agrees it should be used and can be used where experienced men are handling it, but his statement is that it should not be used where inexperienced men are handling it. In a large system, such as that in Chicago, we use nothing but paper cable, even for laterals and secondaries.

There is no difficulty whatever with high-tension cables in taking care of ends if they are provided with pot-heads, as Mr. Newton suggests.

With regard to the facilities which are provided for in emergencies, the pot-head is so arranged that it is an easy matter to have one cable act as a reserve for a group of cables, doing the same class of service, and the developments in recent years are quite numerous as compared with what we used to have to get along with in the way of emergency facilities.

In connection with the ventilation of transformer rooms, I notice that Mr. Newton suggests that any transformer room for 200 kilowatts or more should be ventilated. Our experience is that that is rather a high limit. We have had a number of cases of 150 or 120 kilowatts, where in the summer time the ordinary air temperatures, especially like we had last summer, were enough to make these transformer rooms run up to 130 to 140° F., and the oil temperatures correspondingly high, so that the insulation was in danger. It takes rather a liberal ventilating system in the form of intakes and ventilating flues, etc., to take care of such an installation during warm weather conditions, especially where the transformers carry load continuously on power installations.

With regard to the size of conduits, I think that especially where secondaries are to be run, and where a three-

conductor cable is advisable, the conduit should be at least four inches in diameter. We have had considerable difficulty in Chicago, because of the fact that many years ago we adopted a three and one-half inch conduit as our standard size conduit. When we get up to the point where we would use large three-conductor 20,000-volt cables, we are limited to a diameter of three and one-half inches in the ducts, and 250,000-c.m. cable is the largest we can get into it. That leaves about one-quarter inch clearance which is the least that is practicable, and lengths between man-holes are limited to 350 feet in order to allow the cable to be pulled in.

In any case where large low tension cables are to be used and where three conductors are desirable, I would advise that a 4-in. conduit would be advisable.

B. G. Beck: We have been working with one of these underground systems for a long while. I think when we put in an underground system we should take into consideration the condition of the soil. We have one that the hotter it gets the more it leaks, and the more it leaks the hotter it gets. A great deal of the heating depends on the depth of the installation.

As pointed out, we should take into consideration the proximity of the furnace gas mains and hot water return mains, which may be installed, and another trouble we got into was in following the standard practice that ordinary city engineers used in putting in their duct system. They have really an intermittent service, a period during the day in which their heat goes into the duct systems, and during the night it can be cooled off before getting another big load in the morning, and adding more heat to it. With our system, it is a steady service, six days in the week, and we add heat all the time, and that makes our service quite different from city service.

As to using 16 or 20 ducts in a line, I do not believe I would do it, with the amount of power we have to use in these ducts.

In regard to sectionalized ducts, it is difficult to run the ducts through the steel mill in any case. In most cases you have to run it between furnaces, and when you are running from one center of distribution you cannot sectionalize your ducts.

We ought to take into account the effect of one cable transmitting trouble to another. I believe that has been taken care of by these gentlemen in a very nice way.

I have been thinking of taking out the old duct system, and making a runway through the plant, with a reinforced cover over it, and ventilators about every twenty ft., with air ducts so arranged that we can throw in a fan in case of burnout. We had a serious burnout some time ago when the cables were up to 120 deg. Cent., even those cables which were not carrying current.

With all the troubles to which the underground cable system is incident, there is one thing we must take into account. We have been transmitting about 15,000 kilowatts, 2200 volts, underground, and we have not had any loss of life. The prevention of such loss of life was the primary object in installing an underground system, and we also have not had any motor losses on account of storms or lightning. On some overhead systems with which I have been connected, and on one system in particular, we had a bad lightning storm and lost fifteen motors at one time. That kept us busy for some time. A couple of these motors were big ones on which the plant depended. We have not had any trouble of that kind, but have had trouble with cables. Some of them have been minor troubles, and only one very serious trouble, and the trouble I refer to now was in the case of a cable which started to go bad, and affected the adjacent cable, and that affected the rest of them, and we had our whole duct system hot.

Regarding the running of these wires underground. As was pointed out, when you support the individual cables on porcelain insulators, the question of induction comes in, and it is a question whether with large current carrying capacity we would not run into a lot of trouble with this induction effect, it might be better to install the lead covered cables in a duct system where you could go into it and ventilate it and get your gases out, in case they did blow up.

Barney W. Gilson: I would like very much to hear something from Mr. Gear in regard to the limitations as to size of three-conductor cables. It has been my experience that three-conductor cables larger than 500,000-c.m. are very difficult to handle and install, however, we now have two

500,000-c.m., 3-phase cables in operation, and have some 700,000-c.m., 3-phase cables on order. These last will be laid in floor duct, and not pulled through conduit, as were the 500,000-c.m. cables.

Ludwig Hommel: Mr. Coey's plan of a "tunnel" on the ground instead of under the ground, looks very good, where it is possible to put up such a structure. In fact, I had wondered whether a conduit system with ducts laid on the ground in a few inches of concrete with handholes where necessary might not be feasible in mills having ground water near the surface.

Where a tunnel is used, the cables should be covered for their entire length, just as is done now for the exposed part of the cables in the man-holes. It would be interesting to have Mr. Hovey tell us what is the latest practice, what material is now used for that purpose. If porcelain insulators are used for supporting the cables, the lead sheaths should be grounded to avoid any possible danger to the men handling or touching the lead sheaths.

The planning of the man-hole layout is important to avoid unnecessary crossing over each other of cables in the man-holes. If a diagram is made of each man-hole before the cables are drawn in, showing how the cables will run across ultimately when the duct system is filled, it should result in much better work and avoid trouble in the man-holes.

The trouble with cables, if there is any, mostly occurs in the man-holes where the cable has to be bent—the bending of a cable is an operation that requires skill and experience. If a burnout occurs, it is most likely there to involve other cables.

I believe that junction boxes were mentioned in the paper. It is my experience that they are a source of trouble, while joints are practically as safe as the cable itself.

I agree with Mr. Hovey on the paper cable. I believe that it is fully as reliable as rubber cable and the joints are at least as easily made, and perhaps more easily and safely than on rubber cables.

George T. Street: There is one point which has been brought out in regard to man-holes: the tendency in the past has been to make the man-hole too small. But there is

another point which has not been mentioned, and I think it is important: the tendency to make too few man-holes. Each additional man-hole means additional jointing, but it means much less liability of mechanical damage to the cable in installing it on account of reduction in tension while drawing in, and I think that is one point which should be carefully considered in laying out any conduit system.

Fred H. Woodhull: There is one thing that will have to be guarded against pretty carefully in using the tunnel system. The tendency, where the cables are carried on concrete carriers, where they carry heavy currents, is to have them clamped in some way. They must be held, due to the magnetic effect. I call to mind an experience I had some years ago in connection with central station work in New York City, where a short-circuit occurred back of the switch-board, causing some large lead covered cables to jump off of the cable racks. It is a thing which will have to be guarded against.

A. F. Hovey: In one of the oldest and best known methods for fireproofing cables in manholes against the explosion of adjacent cables, common rope and concrete are employed. The former is wound spirally around the cable with about 1 in. separation between the turns, and the cable and rope are then plastered with a one to one mixture of sand and cement. The rope provides a rough surface to which the concrete clings readily and gives a slightly flexible background, which aids somewhat in preventing cracking of the fireproofing under a chance blow.

The workmen's hands have proved to be better than any tool for applying the cement for this type of covering. As far as the fireproofing qualities alone are concerned, this covering is satisfactory, but its removal presents a formidable task. Efforts to reduce this difficulty have been made by placing the turns of rope closer together and, except for the fact that rope is now rather expensive, this method of protecting cable is fairly satisfactory.

Another method of fireproofing is that in which asbestos millboard, cut into 3-in. strips, is wound around the cable and held in place by a fireproof paste, silicate of soda. This covering proved satisfactory as long as the man-holes remained dry, but if water ran in and covered the cables, the

silicate was dissolved and the asbestos loosened, dropping from the cable. Recently, on account of the difficulty in obtaining deliveries of asbestos millboard, asbestos listing, a woven material with a selvage has been substituted. This material can be purchased in the form of 3-in. tape and wound spirally around the cable, and the silicate of soda covering is used to hold it in place.

When material as expensive as asbestos is used for fireproofing cables, some provision should be made for salvaging the covering when it is removed from the cable. A simple and inexpensive way of doing this is first to wrap the lead sheath of the cable with strips of cheesecloth dipped in paraffine. One layer of cheesecloth is sufficient. Then when repairs are necessary, the asbestos can be separated easily from the paraffined cloth and taken off in long strips. If these strips of asbestos are carefully rolled backward during removal, they can be perserved and reapplied.

In what is perhaps the most recent method of fireproofing underground cables, a layer of paraffined cheesecloth is wound around the sheath and over this metal lath, covered with cement and cut into strips, is spirally wound. The cloth is applied as described above, simply to aid in removing the covering. The metal lath used is a wire mesh covered with brick, clay, put on under pressure and baked, the resultant product being a web of small briquettes which can be applied the same as any wire or expanded metal lath. This makes an excellent foundation for the cement mortar, as it is porous and flexible. The cement can be applied with a trowel or by hand, forming the covering into a homogeneous mass. While this type of covering is somewhat more difficult to install than the asbestos covering, it is considerably less expensive, as calculated from the prevailing prices of material. It can easily be removed by breaking the cement covering with a hammer and cutting the metal lath with tinner's snips.

Whatever covering is applied should be considered good insurance against both mechanical and electrical trouble. The added application of paraffined cheesecloth under any of these types of covering insures the lead sheath against damage at the time the covering is removed for changes in the manhole cables.

I would add one more point in regard to the fireproofing. In constructing the man-holes, the scheme of putting in slate slabs to carry the cable and the joint through the man-holes, particularly in the oblong or egg-shaped type, seems to be a particularly desirable addition to the conduit system itself. It gives a good support, whether the cables are wrapped or not, from one mouth of the duct to the other side. It saves putting in a lot of hangers, and can be installed by putting in T-irons along the wall and the stone or slate slab can be in three pieces, one long piece under the joint, and a section on each side of the joint, and furnishes a good protection from one cable to the other.

T. E. Tynes: One speaker brought up the question of the number of man-holes to install for the duct line. Be sure to get enough. In our new lines we do not bring out all cables in the same man-holes, but only bring out one-half to alternate man-holes. If we lose one set of cables in a man-hole, we are only incapacitated to half the capacity of our cables.

We have also sued the method of wrapping asbestos tape around them to protect them in case of a ground, and that is effective except where there is gas in the man-hole. We have had several bad fires due to leaky gas mains near the conduit line, and the system would fill up with gas, and that gas would destroy anything put in.

If a partial ground occurs on one of the cables, the asbestos covering in the case of dry man-holes is sufficient protection, but this will not work where there is dampness.

H. B. Gear: In regard to the subject of cable protection, we have used the rope and cement wrapping in Chicago for several years now, and I think we have avoided the trouble Mr. Hovey spoke of, (of having the cement stick too tightly to the lead sheaths) by using rather more rope than he described, that is, wrapping the rope so that the spirals almost touch each other. There has been little difficulty in breaking off the rope and cement when it was desirable to get at the cable to do work on it.

There was one point raised about the maximum number of ducts referred to—twenty ducts. I might explain, further, that when anything over perhaps nine ducts or ten ducts is put into one line, it is the practice in Chicago to

separate the conduit system into two halves by putting three inches of concrete between the two ducts on one side and the two ducts on the other side, never putting more than four ducts in any horizontal row, and no duct is more than one duct away from the outside earth, from radiation. This additional barrier of concrete between the two halves of the system is then carried into divided man-holes where the number of cables is sufficient to fill the duct system, and not more than eight or ten cables in that way go into any one man-hole. The man-holes are built in a staggered form, one-half of the conduit system going into one and the other half into the other.

In the vicinity of power houses, where large numbers of cables must be brought out, this problem was solved in our most recent installation by the use of 24-duct runs. These 24-duct runs came out of three or four different buses, and fanned out into 4-duct lines, going to a series of man-holes which led out from three different conduit systems. Three conduit systems went in different ways to the station, and by doubling the man-holes on each of the conduit systems, and fanning out a group of 4 from each of the 24 into the man-hole, all of the cross-overs were taken care of underground and a system was devised by which a cable could be brought into any conduit system or by which we have no cross-over in a man-hole.

With regard to the maximum size of conductor which might be put into a 3-conductor cable, I do not know that I can answer the question specifically. I have known of cables as large as 600,000-c.m. being used. The real limit, I think, as I stated before, is in the size of the conduit which is used. With a 4-inch conduit system, I think there will be no difficulty in using three 600,000-c.m. or possibly three 750,000-c.m. conductors in one three-conductor cable.

In reference to using a tunnel large enough for men to walk through, I would be inclined to think it would be preferable, even if such tunnels were used for low tension cables, to use 3-conductor cables carried on a rack rather than to use single cables carried on separate racks which would necessarily have to be three or four inches apart. The inductive effect as well as the safety of installation, would be bettered by the use of three-conductor cables.

STEEL CONDUCTORS FOR TRANSMISSION LINES ✓

By H. B. DWIGHT

The results of a number of tests of the electrical properties of steel wires and cables when used as conductors of alternating current, have been published. Although these tests are incomplete, especially as regards the use of steel conductors in America, they show some attractive possibilities, from both commercial and engineering points of view, for the use of steel instead of copper in certain classes of work.

Attention is here called to the peculiar properties, the advantages and disadvantages, of steel conductors, in order to point out the advisability of making complete tests of American grades of steel, so that electric power companies may make use of this material for the cases where it proves economical and advisable for transmission-line work. Already, small sizes of steel conductors have been used with success in America, and this practice may be extended by a knowledge of the characteristics of large steel cables.

As is well known, resistance of an iron or steel conductor is considerably greater for alternating current than for direct current. This is partly due to the skin effect, that is, the crowding of the alternating current to the outside parts of the conductor by the alternating magnetic flux in the conductor, and partly to hysteresis, or iron loss, caused by the alternating magnetic flux in the steel. In the case of copper or aluminum transmission-line conductors of usual size, the skin effect increases the effective resistance only one or two per cent. and so is practically negligible. But in the case of iron or steel conductors, the flux has a magnetic path, and so attains a value from 20 to several hund-

red times as great as in a non-magnetic conductor. The result is that the skin effect is very pronounced and the effective resistance is increased by a large amount, in some cases by 100 or 200 per cent. or more. However, the conclusion should not be assumed that steel cables are unsuitable for alternating currents. The tests so far published go to show that it is as necessary for an iron a-c conductor to have fine strands as for an iron core to have thin laminations. The tests also indicate that if the strands are moderately fine and are properly put together, the increase of resistance at 25 or 60 cycles may be kept down to a reasonably small percentage. This is shown in Figs. 1 to 6.

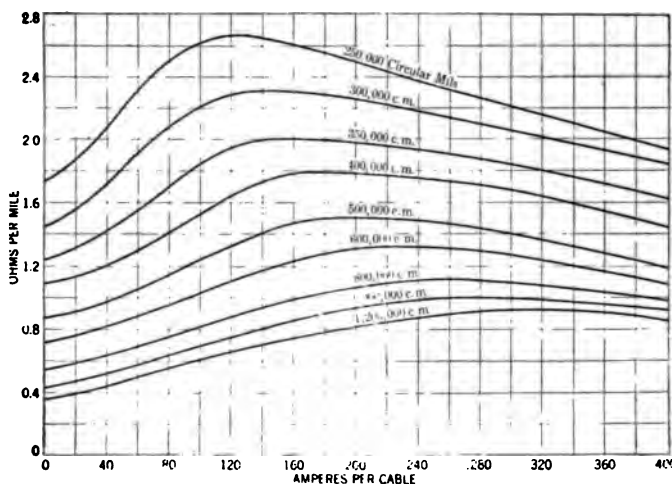


Fig. 1—Resistance Curves—60 Cycles—49-Wire Cables—Grade H-oo Steel

The curves shown with this paper have been derived from test curves published in the *Elektrotechnische Zeitschrift* of January 28, 1915. They refer for the most part to a grade of steel or iron, called H-oo, which is a medium grade recommended in the above article for alternating-current work. That its cost is reasonably low is indicated by the fact that two other grades of steel were tested, each stated to be purer and more expensive, and also to have greater skin effect, than the grade H-oo. Although the purer material has higher conductivity for direct current, it has also greater permeability to magnetism, which is a

disadvantage. Thus the cheaper grade was found to be more suitable for a-c. work. The same conclusion was also stated in a recent bulletin, No. 252 of the Bureau of Standards, Washington, D. C., by J. M. Miller, who found that of the wires tested, the grade with the highest resistance to direct current had the lowest resistance to alternating current, and was also the least expensive. The tests on American steel wire described in the above bulletin shows somewhat less skin effect than that of grade H-oo steel wires.

The tests on grade H-oo steel were originally expressed in centimeter units and were made at 50 cycles. The curves

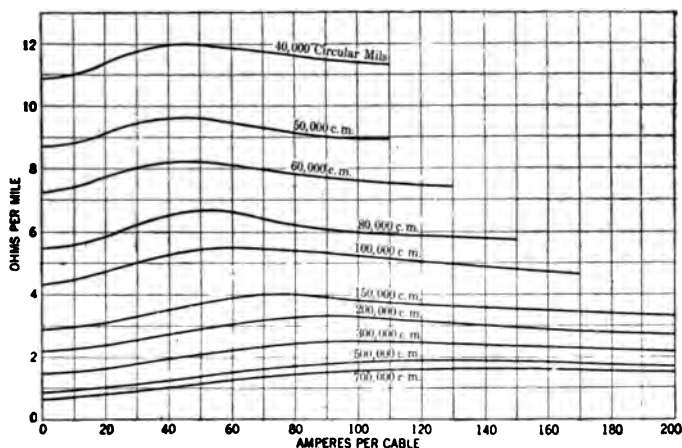


Fig. 2—Resistance Curves—60 Cycles—19-Wire Cables—Grade H-oo Steel

have been re-arranged for English units and for 60 and 25 cycles, and put on a base of amperes per cable, so as to apply to American transmission-line conditions. The Bureau of Standards' tests described in Bulletin No. 252 show that at commercial frequencies the increase of resistance is approximately proportional to the frequency, and this property was made use of in making the above transformations.

The curves of internal reactance of steel cables published in the article referred to above, are shown in Fig. 7. These curves do not refer to grade H-oo steel, but to a grade of higher permeability. This grade, as shown by resistance curves in the original article, has more increase of resistance

than grade H-oo, for the same size and stranding of cable. Presumably, therefore, grade H-oo would have somewhat lower values of reactance than those of Fig. 7. The tests show that the resistance curve and the reactance curve of a given cable reach their maxima at about the same value of current. It is of interest to note that increasing the number of wires in a cable decreases the reactance, while increasing the size of the wires increases the reactance, according to the examples in Fig. 7.

The d-c. resistance of each cable is given in Fig. 7, and the maximum a-c. resistance will be about twice as great,

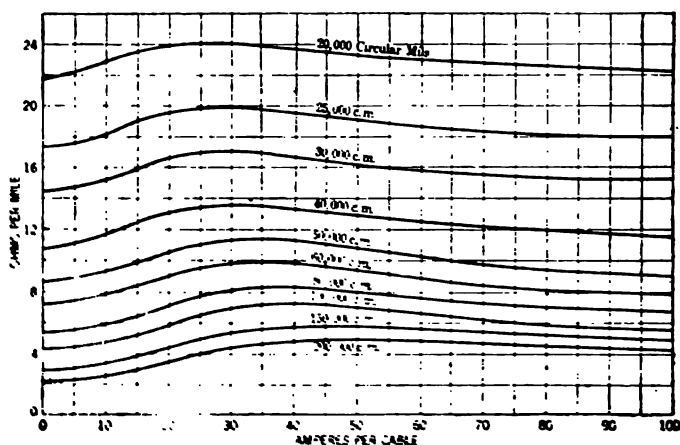


Fig. 3.—Resistance Curves—60 Cycles—7-wire Cables—Grade H-oo Steel

according to Figs. 1 to 6. From the results shown in Fig. 7, the internal reactance at 60 cycles and at any current may be taken as being about 75 per cent. of the a-c. resistance at the same current in the absence of more complete data. The external reactance should be taken from regular transmission-line tables and added to the internal reactance to give the total reactance. The above is the method by which the examples at the end of this paper have been worked. It is merely approximate, and the caution should be given that for practical designing, test curves of the resistance and reactance of the actual type of cable to be used should be employed.

Another point brought out by the tests in the *Elektrotechnische Zeitschrift* is that a large part of the magnetization is caused by the spiraling of the wires in a cable, and if the spiraling of the different groups of wires is properly

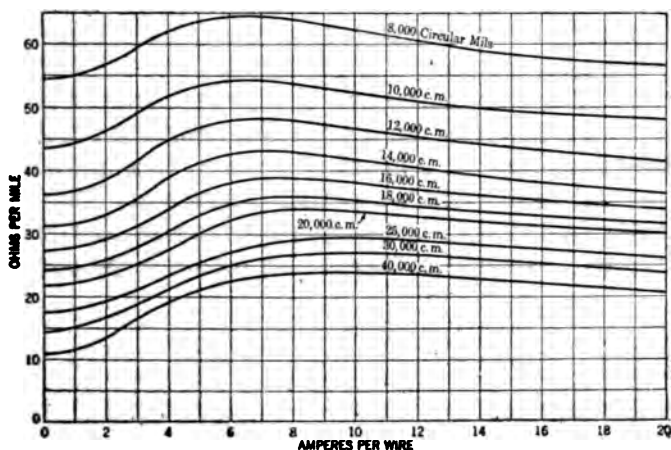


Fig. 4—Resistance Curves—Grade H-00 Steel Wires—60 Cycles

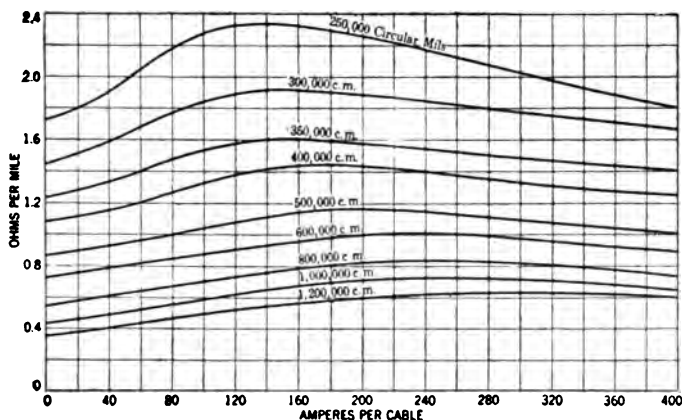


Fig. 5—Resistance Curves—25 Cycles—49-Wire Cables—Grade H-00 Steel

reversed, the increase in effective resistance can be reduced as much as one-half. Actual examples of this are shown in Fig. 8. Thus if the spiraling of one layer of wires is clockwise, the spiraling of the next layer should be counter clock-

wise. Also, in a cable made up of several strands, the spiraling of the wires in each strand should be opposite to the spiraling of the strands in the cable. In Figs. 1 to 6, the cables are assumed to have the spiraling reversed as much as possible. Since spiraling produces so strong an effect, the pitch of the spiral should be as long as possible without endangering the strength of the cable.

The curves accompanying this paper show that iron and steel conductors have the peculiar property that the effective resistance and reactance increases to a maximum as the current is increased, and then decreases. This is due evidently to the iron becoming saturated so that the flux and the iron loss do not increase as before in proportion to

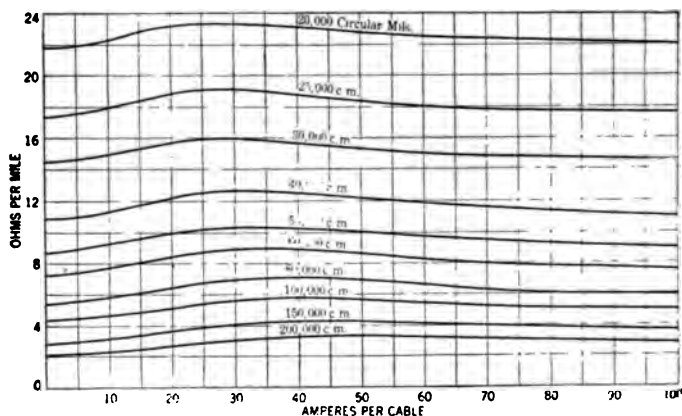


Fig. 6—Resistance Curves—25 Cycles—7-Wire Cables—Grade H-00 Steel

the current. In most cases, especially with the larger cables, the decrease is very slow and the resistance maintains approximately its maximum value for most large values of current. This property should prove useful in transmission-line work, for the conductor will have a low impedance to the normal load current, but will have about twice as much impedance to the current flowing in case of a short-circuit. The impedance will also be large to high-frequency surges caused by switching or lightning. It may prove more economical in certain cases to protect a line against short circuits and surges by using steel conductors than by install-

ing current-limiting reactors or by increasing the reactance of the transformers.

This property may also be of use in the case of feeders of direct-current interurban railways. If the feeder be a steel cable it will have low resistance to direct current, but high impedance to alternating currents. It will therefore tend to damp out the suddenness of short circuits, and lightning surges, which cause synchronous converters and generators to flash over. That there is need of taking precautions against flash-overs in this way is shown by the fact that it has already become the practice to make the nearest connection between a feeder and the trolley wire

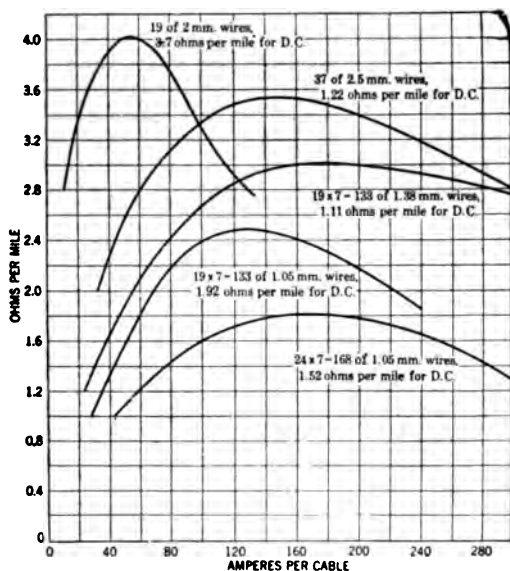


Fig. 7—Internal Reactance Curves—60 Cycles—Grade S.S.W. Steel

several thousand feet from a synchronous converter or generator so that the latter will be protected by the resistance of a long stretch of feeder in case of surges or short circuits.* If the feeder be made of steel, and especially if the stranding be coarse, the required protection will be still more complete. Steel conductors would probably be econo-

*The Relation of Trolley Feeder Taps to Machine Flash-Overs, by Chas. H. Smith, The Electric Journal, January, 1915.

mical only where it is allowable to use bare cables, for the large size of steel cables compared with copper ones would greatly increase the cost of the insulating covering.

The higher conductivity of steel for direct current than for alternating current makes the use of bare steel cables for d-c. feeders more economical than for a-c. lines. A steel cable has about eight times as much resistance to direct current as a copper cable of the same size, and therefore seven times as much resistance as a copper cable of the same weight, since copper is more dense than steel. But galvanized steel cables usually cost less than 1-7 as much as

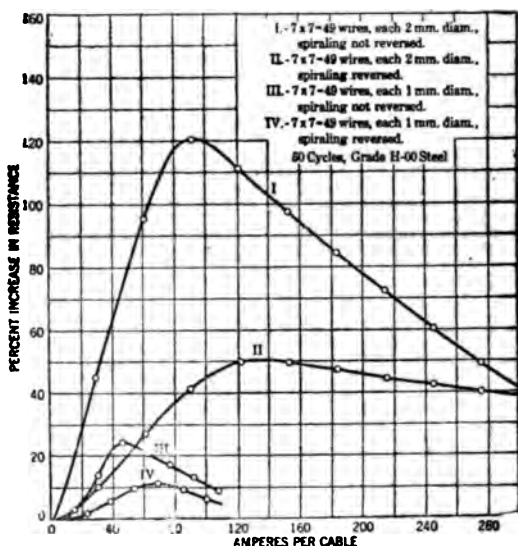


Fig. 8—Effect of Spiraling

copper cables per pound, and so should be more economical, other things being equal.

Steel cables have frequently been used on transmission lines for long spans up to 3000 feet or more. In some cases the steel cable has been the support for a copper conductor, but in many cases the steel cable itself has carried the electric current. Such applications are of such a short length compared with the entire transmission line that they have been chosen, not because of a comparison of the cost and conductivity of steel and copper, but because copper or alu-

minum would be too weak for such long spans, and a much stronger material, like steel, was absolutely necessary in order that the transmission line should be mechanically safe.

Another application of steel conductors which has already met with fair success is for small size conductors, as mentioned in the second paragraph. Here again it has not been relative conductivity, but the greater tensile strength, which has induced the choice of steel rather than copper. It is not the practice to use a smaller copper wire than No. 6 (0.162 in. or 4 mm. diameter) for overhead lines, because any smaller copper wire would be mechanically too weak. But it is often profitable to supply a small load at a distance of several miles, which would require only a fraction of the conductivity of a No. 6 copper wire, and in such cases a No. 8 or larger steel conductor has been found to have sufficient conductivity and mechanical strength, and to cost much less than No. 6 copper.

According to a description recently published,* a large 60-cycle power system in the State of Washington makes use of a considerable quantity of No. 8 iron wire for short tap-offs and lightly loaded branch lines on 6600-volt circuits, without serious trouble resulting from voltage drop. This iron wire is of course far cheaper than No. 6 copper. One line built by the above company is an example showing that it may be profitable to supply a surprisingly small load at a distance of several miles. This line is 10 miles long and was originally built with No. 8 copper clad steel to supply a 50 h.p. motor load at 6600 volts. The line afterward carried 110 h.p. for some time and was later changed to No. 6 copper in order to have a capacity for a still greater load.

An example from Minnesota shows the use of somewhat larger steel conductor. This line operates at 40,000 volts, 60 cycles, and is 20 miles long. No. 4 galvanized steel cable, made of 3 wires, is used. The load is about 300 kv-a.

The above examples show that a power company can build up new loads by sending out to considerable distances numerous inexpensive lines, using small steel conductors. The cheapness of the lines and of the outdoor transformers

*The Electric World, p. 469, Aug. 28, 1915. See also similar examples described in the Electrical World, p. 820, April 8, 1916.

makes a very small load profitable, and the chances of obtaining larger loads are increased by building lines into new territory. Most of the small steel conductor lines appear to use solid wire of the kind which has been developed and sold for telegraph and telephone work, but a stranded cable would seem, according to the test referred to in this paper, to be more suitable for a-c. transmission of power.

A line with small conductors, where steel is cheaper to employ than the minimum size of copper, is described in Example I. Here, a seven-mile steel line can be designed for 75 kv-a., but the smallest copper line that can be designed would be rated at 750 kv-a. Thus, while the poles and insulators will be the same in both cases, the steel conductors will cost only \$220 against cost of \$2600 for copper. It is this large difference in cost which has been the main reason for using steel conductors on the branch lines of the power systems previously mentioned. This difference in cost of course is greatest when the price of copper is highest.

Besides being cheaper than the copper cable for small branch lines, the steel cable has the advantage of being mechanically stronger and less liable to be burned through by arcs. The steel line has therefore greater reliability at times of wind and sleet storms and at times of electrical breakdown or trouble. Steel cables are subject to the disadvantage that their useful life is shorter than that of copper cables, especially near the sea-coast where galvanized steel is more quickly oxidized.

Example I shows also the advantage of using fine stranding. The seven-wire cable gives 9.6 per cent. drop, while a solid steel wire of the same cross section has 12.5 per cent. drop at the given load, according to the tests of grade H-00 steel.

Examples II and III show comparisons at 60 and 25 cycles between steel and copper conductors in regular transmission line work where the conditions are equal for competition between the two materials. The price of copper cable per pound may be assumed as being 10 times that of galvanized steel cable. This ratio is a usual one, being approximately true for times of low prices of metals as well as times of high prices. The lack of data on the reactance of a steel transmission line makes comparisons somewhat

uncertain, but from the available data it seems probable that, considering the line complete with towers and insulators, it will cost for 60 cycles quite as much to use steel conductors as copper, for heavy transmission-line work, where the extra weight of steel cables is troublesome. For 25 cycles there may be a saving by using steel. However, there are many cases where the extra strength and size of steel cables are advantageous, and so at present the chief attention should be given to the classes of work where steel can show other advantages than merely low cost on a basis of carrying capacity for alternating current power.

A transmission voltage of 100,000 or more is now fairly common. It is also a matter of observation that the cost of high-tension substations of the above voltage is decreasing, especially where outdoor substations are used. It is not possible to use a small copper or aluminum conductor on a 100,000-volt line on account of corona loss, as is indicated by the corona limits of voltage given in examples II and III.* Therefore the phenomenon of corona puts a limitation on the smallest allowable conductor of a 100,000-volt branch line, in exactly the same way that mechanical strength fixes the minimum size of wire for a low voltage line, as previously described. Therefore, steel conductors have an opening for use on branch lines supplying a few thousand kv-a. on net works of 100,000 volts and higher. This is especially true in mountainous districts, where corona limits of voltage are lower, and where the other advantages of steel lines, namely mechanical strength and ability to resist burning by high-tension arcs, are especially valuable. In rugged country, also the long spans permissible with steel cables may often save detours, and shorten the distance of transmission. There is also the probability, previously mentioned, that where steel conductors are employed, lightning and switching surges will be damped out more than where copper conductors are used.

In conclusion, it has been shown that large steel cables, if properly manufactured, can be used for carrying alternat-

*These limits have been calculated according to the tables in "Dielectric Phenomena," by F. W. Peek, Jr., page 210, McGraw-Hill Book Co., New York, 1915.

ing currents. It appears that the chief opportunity for the use of steel conductors is on branch lines, where the size of copper required merely for the electrical load would be too small to use. However, in all cases, steel conductors will be nearly as cheap as copper ones, if not more so, and the use of steel will always increase the reliability of the transmission system.

EXAMPLE I

Length of line	7 miles
Voltage at receiver	11,000 volts
Frequency	60 cycles
Power factor of load	85 per cent.
Phases	3
A. Conductor	7-wire steel cable
Size	25,000 cir. mils.
Diameter of cable	0.18 inches
Diameter of Wires	0.06 inches
Resistance per mile at full load	17.6 ohms
Full load	75 kv-a.
Voltage drop at full load	9.6 per cent.
Weight of Conductors	7300 pounds
Cost of steel cables at 3 cents per lb....	\$220
B. Conductor	Single steel wire
Size	25,000 cir. mil.
Diameter	0.158 inches
Resistance per mile at full load	23 ohms
Full load	75kv-a.
Voltage drop at full load	12.5 per cent
Weight of conductors	7300 pounds
Cost of steel wires at 3 cents per lb. ...	\$220
C. Conductor	Single copper wire
Size	No. 6, 26250 cir. mils.
Diameter	0.162 inches
Resistance per mile	2.14 ohms
Full load	750 kv-a.
Voltage drop at full load	9.5 per cent.
Weight of conductors	8800 pounds
Cost of copper wire at 30 cents per lb...	\$2600

EXAMPLE II

Length of line	75 miles
Voltage at receiver	60,000 volts
Frequency	60 cycles
Phases	3
Power factor of load	85 per cent

A.	Number of circuits	2
	Conductor	49-wire steel cable
	Size	400,000 cir. mil.
	Diameter of cables	0.81 inches
	Diameter of wires	0.09 inches
	Full load per circuit	2500 kv-a.
	Resistance per mile at full load	1.16 ohms
	Voltage drop at full load	9.6 per cent
	Weight of conductors for two circuits...	2,510,000 pounds
	Corona limit for operating voltage at 1000 ft. above sea level	164,000 volts
	Sustained short circuit kv-a. at full gen- erated voltage, transformers with 5 per cent reactance being included at each end	4.4 times full kv-a.
B.	Number of circuits	1
	Conductor	49-wire steel cable
	Size	1,000,000 cir. mil.
	Diameter of cable	1.28 inches
	Diameter of wires	0.143 inches
	Full load	5,000 kv-a.
	Resistance per mile at full load	0.54 ohms
	Voltage drop at full load	10.9 per cent
	Weight of conductors	3,140,000 pounds
	Corona limit for operating voltages at 1000 ft. above sea level	230,000 volts
	Sustained short circuit kv-a. at full gen- erator voltage, transformers with 5 per cent. reactance being included at each end	3.8 times full kv-a.
C.	Number of circuits	1
	Conductor	7-wire copper cable
	Size	No. 1, 83,700 cir. mil.
	Diameter of cable	0.328 inches
	Resistance per mile	0.678 ohms
	Full load	5,000 kv-a.
	Voltage drop at full load	10.7 per cent
	Weight of conductors	300,000 pounds
	Corona limit for operating voltages, at 1000 ft. above sea level	85,000 volts
	Sustained short circuit kv-a. at full gen- erator voltage, transformers with 5 per cent. reactance being included at each end	4.8 times full kv-a.

EXAMPLE III

Length of line	100 miles
Voltage at receiver	60,000 volts

Frequency	25 cycles
Phases	3
Power factor of load	85 per cent
A. Conductor	49-wire steel cable
Size	700,000 cir. mil
Diameter of cable	1.08 inches
Diameter of wires	0.12 inches
Resistance per mile at full load	0.68 ohms
Full load	4,000 kv-a.
Voltage drop at full load	10.2 per cent.
Weight of conductors	2,930,000 pounds
Corona limit for operating voltage at 1000 ft. above sea level.	215,000 volts
Sustained short circuit kv-a. at full gen- erator voltage, transformers with 5 per cent. reactance being included at each end	4.7 times full kv-a.
B. Conductor	7-wire copper cable
Size	No. 2, 66,400 cir. mil.
Diameter of cable	0.292 inches
Resistance per mile	0.855 ohms
Full load	4000 kv-a.
Voltage drop at full load	10.2 per cent.
Weight of conductors	316,000 pounds
Corona limit for operating voltage at 1000 ft. above sea level.	76,000 volts
Sustained short circuit kv-a. at full gen- erator voltage, transformers with 5 per cent. reactance being included at each end	5.6 times full kv-a.

DISCUSSION

Robt. E. Doane: Mr. Dwight has presented to us a comparatively new subject which has been little discussed by the engineering world in the past and which is of interest because of the possibility developed in certain directions. We would point out, however, as Mr. Dwight himself states, that the application is limited to certain special cases.

There are four general classes of service in which steel wire might be used to advantage.

1. Trolley wire.

2. Very lightly loaded high voltage lines, which are not long.

3. Very high voltage power transmission lines where the question of corona loss becomes of great importance.

4. Long spans.

In the first case the use of steel trolley wire has been quite extensively adopted in certain directions with somewhat variable conclusions as to its relative cost and general efficiency. In this field, the use of steel is restricted to certain sections of our large cities where the traffic is very dense and where the large portion of the current must of necessity be carried on auxiliary feeder lines, with very frequent taps to the steel trolley wire. In such special cases the resistance drop and consequent power loss in the steel as compared with copper is comparatively negligible, because the current has to flow along the steel but for a short distance only. Due to the greater hardness of steel, and its original first cost, together with its supposed longer life under operating conditions, it has had preference in certain cases. However, the very serious questions of corrosion and scrap value of the worn-out wire have to be taken into consideration and these are very important items which will be mentioned later.

There is another field of steel trolley wire where, as in such installations as on New York, New Haven & Hartford Railroad, it is necessary to have an exceedingly flat and smooth trolley wire for high speed work, in which cases the wire is sometimes suspended directly under a copper wire, purely for mechanical and not electrical reasons. In both of the above cases hard bronze wire is also used to advantage.

The second class of service, for which steel is applicable, is in the case of moderately high-voltage lines where very light loads are carried over distances that are not great. In such cases the smallest copper wire that would be used for mechanical reasons is, as Mr. Dwight mentions No. 6 B&S, although in a great many cases No. 8 B&S has been employed for such service. This of course depends upon the climatic conditions, danger from high wind velocity, sleet and snow and distance between towers or poles, amount of allowable sag, and other considerations. There are undoubtedly cases where the smallest copper wire that could

be used from the mechanical standpoint would be much heavier than would be necessary to meet the required electrical conditions of reactance drop and carrying capacity. In such cases the use of steel will be found to be economical, but here again the steel field is limited.

The third class of service, that of very high-voltage lines, where the question of corona loss becomes important is a field which has not yet been extensively covered in engineering discussion due to the fact that there are few such lines. There are probably not more than half-a-dozen such lines in the United States. Here again the field of application must necessarily be limited.

The fourth class of usefulness, that of long span work has been more extensively discussed. There are some notable examples of long steel spans, and some combination steel and copper cables such as the long span in use by the Mississippi River Power Company of Keokuk, Iowa, a discussion of which was printed in the proceedings of the A.I.E.E. for October, 1914. It is well to point out that there are very few long spans which can not be made with a reasonable factor of safety using copper wire, provided that there is a possibility of allowing sufficient sag in order to somewhat reduce the tensile strain on the wire. The very slight increase in the percentage sag and consequent increase of the height of towers, which may be necessary in some cases, would make it mandatory for the engineer to decide on copper rather than steel. Of course in cases where additional expense in height of towers is made necessary the increase in the cost of steel towers may more than offset the advantage to be obtained from the use of copper in the span.

In making general calculations covering any particular installation, it would be logical to first assume that copper would be the natural metal to use and steel the unnatural, due to the fact that the vast majority of all transmission lines, trolley lines and long spans have in the past been constructed with copper and generally for good reasons. The percentage use of steel as compared with the copper is very slight indeed.

SCRAP VALUE AND CORROSION

There are two general conditions which make the use of copper generally mandatory, the principal one of which is the ultimate scrap value of the material used. By throwing out the consideration fluctuations, in the cost of metals, which is proper in a theoretical discussion, it may be assumed that the scrap value of copper is in the neighborhood of 85-90% of the original purchase price. The scrap value of steel would probably be so low as to hardly warrant consideration, particularly if the line in question were a long distance high voltage line extending across wooded or mountainous districts where the cost of salvage would be exceedingly high. The whole question as to the use of copper is an economic question, except for certain very special and rare cases. Lines are constantly being changed and altered and the scrap value is of great importance. It is of extreme importance in the case of trolley wire, which is frequently replaced and even if the copper trolley wire should be reduced 50% in cross section, the scrap value may still be 40% or more of the original cost.

The question of corrosion and life of the material is intimately connected with the scrap value. This is largely a question of climate, although the relative corrosion of copper and steel is probably about the same in most climates. It is unquestionably true that steel corrodes more rapidly than copper and its life is correspondingly shortened. In long distance transmission lines, one of the primary considerations is continuity of service and if steel wire were used, subject to fairly rapid corrosion, it would necessarily be thrown out of consideration due to possibility of breaks occurring at unexpected times, perhaps many miles away from the nearest town, all of which would be exceedingly expensive and require a shutdown of many hours or even days before the trouble could be repaired. If copper lines are properly strung and not overstrained, this danger would be appreciably less.

Bear in mind that there are certain sections in the country where even the life of copper wire is comparatively limited and at best, lines have to be restrung quite frequently. In certain locations on the Pacific Coast the life of copper transmission line is but a very few years and in central

Pennsylvania in certain localities, in the coke regions, copper is also attacked very rapidly by corrosion. Steel would probably go much faster than copper in such localities, and since the scrap value of copper is so enormously greater than the scrap value of steel, copper would almost of necessity be used under such conditions.

Mr. Dwight has mentioned the use of copper-clad steel wire which is being adopted in increasingly larger fields very rapidly. It combines the higher tensile strength of the steel, and offers 30% or 40% conductivity of copper as against approximately 14% conductivity which the steel possesses. Its use has been very extensive indeed in the small size conductors and it has given a very satisfactory account of itself.

In discussing the commercial aspect of the case we note that Mr. Dwight has stated that the price of copper per lb. may be assumed as being ten times that of galvanized steel cable. If the present relative cost of copper and steel is a criterion, this ratio is hardly a fair comparison, for copper is in the neighborhood of 30c per lb. and we believe that base size E. B. B. galvanized steel wire is over 6.0c per lb., so that roughly, copper would cost about five times that of steel rather than ten times. Undoubtedly some of the steel men present can comment on these figures.

Mr. Dwight has very naturally and properly chosen examples in which cases the use of steel would be more advisable and has very clearly shown in certain cases that it is worthy of careful consideration. It would, however, be unwise to consider that its use is of general application and in working out specific problems we must in all cases put both metals on an equal footing, standing strictly on their relative merits, commercial costs, and consequent applicability. In other words the question is purely an economic one, and in the vast majority of cases, copper will undoubtedly be found the least expensive, all things considered.

Mr. Dwight has made an excellent presentation of this subject and it is worthy of very careful thought.

T. H. Worcester: Mr. Dwight's paper gives valuable additional data on the subject of iron and steel electrical conductors and will be of considerable assistance to engineers in designing circuits in which such conductors may be

used. The data which has previously been available is so scattered and meagre that it has been difficult to find information on a chosen size and quality iron wire or even to interpolate between known values on given sizes and qualities. With the help of Mr. Dwight's data this will be much simplified, since he has given information covering a wide range in sizes of wires, in current densities and in methods of spiraling. It is unfortunate that a greater range in quality of material is not covered and moreover that the principal quality considered is not a duplicate of American product so that direct comparisons might be made. Tests on effective resistance which we have made on $\frac{1}{4}$ " $\frac{3}{8}$ " and $\frac{1}{2}$ " seven strand steel of the Siemens-Martin grade correspond very closely to the results shown in Figures 3 and 6. Our tests were not made with as high current values as those shown by Mr. Dwight, so that the drooping characteristics of the upper end of the curves has not been checked. However, this droop in the curves is what one would expect after the iron reaches saturation and the general character of the curves has been checked on other grades and sizes of wire.

As regards the internal reactance of iron cables, the value of 75% of the a-c. resistance for corresponding currents seems to be high except for conductors having diameters greater than $\frac{1}{2}$ inch or those made of iron having relatively high permeability. The tests mentioned above on steel wire show the reactance to be about 30% of the resistance for $\frac{1}{4}$ " and $\frac{3}{8}$ " cables and 50% for $\frac{1}{2}$ " cable. However, this is subject to such variation with permeability and current density that it is very desirable to test samples of the conductor which it is proposed to use if accurate values are desired.

One of the interesting points about iron wire conductors is that the purer and more costly grades of wire have higher effective resistance and reactance on a-c. than the cheaper grades of steel wire, even though the latter have higher resistance on d-c. In considering this point, however, it must not be forgotten that the high grade iron wire will not deteriorate as rapidly as steel wire after the galvanizing is once scaled off and that in some cases it may be more economical.

The advantage of using many small wires stranded together with reverse spiral in alternate ropes is worthy of careful consideration. From a theoretical electrical standpoint such cable is to be preferred. In practice, however, finely stranded cable may prove troublesome from breakage of the wires either by rusting through or by short circuit arcs. Furthermore, finely stranded cable when each wire is galvanized as it should be, is considerably more costly than coarsely stranded wire. For the larger sized cables— $\frac{1}{2}$ " and above—the 7 x 7 strand is permissible, but for the smaller sizes its use is questionable.

In view of the fact that there will be a continual demand for steel conductors in the future it is very desirable that more complete data be obtained on American grades at as early a date as possible.

David B. Rushmore: A subject of this kind is always of interest, because of changing conditions, and with the present prices of copper and aluminum, and because of the price today for steel and iron, which will probably be reduced before the others are, there will undoubtedly be, from a purely economic standpoint, a certain field for the use of steel conductors. That these have been used, and are being used, to some extent, has been mentioned in the paper—in small installations, often where the western lines run out a very small line at high voltage to a prospect—a mine may be developed later, but they are not quite sure, and the man himself just wants a little power for drilling and hoisting. Nobody knows what the future condition is going to be, so that the minimum of installation expense is usually the first consideration, and the efficiency is not of the first importance.

There are some very interesting points in regard to the deterioration of iron and steel under weather conditions. Those of you who have visited the Panama Canal will remember there is a lot of old French machinery, made in Belgium, which is still around there in heaps, or was a few years ago when I was there, and not rusted at all, with no sign of deterioration on it. Having occasion to look this matter up, to see what it was, I found that it is puddled iron, wrought-iron, and the apparent reason is that the little grains or globules of iron are covered by silicate flux which

prevents the oxidation of them. As is known, a wrought-iron roof will stand practically indefinitely without rusting. Whether that is a metal which could be used as a conductor or not, I am not sure.

There is an interesting phase about the use of iron and steel conductors, in the rather able presentation of the paper and the discussion which has been had and has covered most of the points, that has not been mentioned, and that is its protective action against high frequency disturbance. A patent has been taken out by an Italian engineer for covering copper-clad conductors with a nickel covering of high resistance so that the action of the high frequency current in what is known as skin effect, forcing the conductor to the outside of the duct, forcing it into a cylinder of very high resistance, which absorbs the energy of surge and prevents it from passing along the line. Some such effect as that would be brought about in high frequency disturbances which would have to stay in or on the steel, and which would be absorbed more readily than in a conductor of lower specific resistance.

It is apparent that later on this sub-division of conductors in cables, is highly desirable, and the great pressure now being put forth for the use of higher voltages—there are quite a number of active propositions at present for 200,000 volts—is forcing the conductor up to the limit of corona, so that the size of the conductor is determined much more by corona than by the current capacity, and the size of the conductor will, for small lines, be quite independent of the load transmitted. So, in many special cases, the steel conductors can be considered at the present time, and as has been said, it is a subject which is worthy of careful scientific investigation and of much more careful commercial study.

S. C. Coey: I had one question I would like to ask Mr. Dwight on the curve Fig. 1. I wonder if he has any explanation to offer as to why the curve for the smaller sized wire should have a higher heat than for the larger sizes. It apparently is while the iron or steel is becoming saturated and it would seem to me you would have about the same for different sizes.

W. T. Snyder: It occurred to me in connection with the use of steel wire there would necessarily be connections

and some of the taps made with copper wire, small copper feeders branching off. I wonder what the electrolytic effect would be there, what chemical action would take place, if that would result in any undue harm? I understand that in the case of the use of copper-clad steel, if the copper envelope is scratched, and the steel is exposed, that chemical action is set up between the two elements and it rapidly destroys the wire. I wonder if the same effect would take place at the tapping of a copper wire onto a steel wire? Also, in the case of tapping of a steel wire onto another steel wire, what is the method of splicing to prevent holding water and bringing about rapid corrosion?

David B. Rushmore: It might be possible that some one here would be able to suggest a solution to a point which has not up to date been forthcoming. There have been put into use, in the past few years, a number of transmission lines of copper stranded cable with hemp centers. This, in general, has been very disastrous. In the case of one line, which was put in in South America, a cable after a period of a year or two went all to pieces. There was some action which took place between the hemp center and the copper adjacent to it which corroded the copper badly and there was evidently a chemical action which penetrated the copper for about one-quarter of the diameter.

I saw sections of the cable which were sent north, and in all our efforts we were never able to get a satisfactory explanation as to what the cause of the trouble was. The use of such copper cable, with hemp centers, has, so far as I know, been almost entirely discontinued.

The longest practical transmission line I know of, is one feeding into Los Angeles, from a point about 250 miles distant to the north, a line of the Pacific Light & Power Company, which is operating at 150,000 volts, and it is interesting to learn that they are having very little operating trouble with it. The cable there consists of a steel center, both for strength and to increase the diameter of the conductor, with stranded aluminum around and outside, and there was considerable discussion just on the point brought out, whether there might not be, as the effect of rains and moisture saturating the cable, electrolytic action which would tend to destroy it. The practical result of that would prob-

ably appear within a year or two, but there is no evidence up to date to show what it will be. Why the cable with the hemp center and copper conductors should have gone to pieces as it did, the copper becoming extremely brittle and cracking at right angles to the length of the wire, has never, so far as I know, been explained.

H. B. Dwight: In reply to the question why some of the curves in the paper have sharper peaks than others, I believe this is merely accidental, depending on the relative magnitude of the scales to which the curves were plotted.

Regarding the electrolytic action at a joint between a steel cable and a copper cable, it may be necessary to protect such joints from the weather, but the action is not to be considered as an objection to the use of steel cables. In the descriptions of practical operation referred to in the paper, it was stated that this trouble was feared, but that no trouble was experienced.

Mr. Doane's discussion was very interesting and has added considerably to the complete description of the standing of steel conductors in commercial work at the present time. The steel conductors used at present are undoubtedly a small percentage of the copper conductors used, but this ratio may be changed by the high price of copper and by an increase in the knowledge of the alternating-current properties of commercial steel cables.

Mr. Doane stated that the ratio of cost of copper to steel should not be 10 to 1 as given in the paper, but should be 5 to 1 as shown by the price of "extra best" iron wire. It is pointed out in the paper that according to the tests published in Germany and also tests made by the Bureau of Standards, pure iron is not the best for alternating-current work, and there is good hope that the grade of steel most suitable for power lines will cost only one-tenth as much as copper.

With reference to the statement that there are only a half dozen lines in America where corona loss is important, it is evident that a pressure of 150,000 volts is referred to, but it is easy to show that corona is of importance at the very common pressure of 100,000 volts. Two values of corona limit of voltage are given in the paper, namely, 85,000 volts for No. 1 copper and 76,000 volts for No. 2 copper at a usual spacing. Although such small conductors are some-

times used on 100,000-volt lines, the practice is probably not economical or advisable, owing to the heavy corona losses in bad weather. Accordingly, on branch lines of 100,000-volt systems, there is an opportunity for the use of steel cables which would have lower conductivity and cost than No. 1 copper, but would have larger diameter and would be free from corona loss.

Mr. Worcester in his discussion emphasized the value of curves similar to those in the paper, but applying to American steel cables. I believe that in view of the small cost of making the tests, it is proper to urge that test curves be prepared and published, of several grades of American commercial steel cables of medium strength and cost.

CONTROL OF D-C. AND A-C. MOTORS AS APPLIED TO CRANES

BY PAUL CALDWELL

It might safely be said that cranes and kindred machines used in the handling and transporting of steel in its various processes of manufacture constitute about one-half the number of connected motors in a modern steel plant, exclusive of motors applied to main roll drives which are now coming into universal use. There is possibly no other industry where these forms of transportation are so extensively employed as in the manufacture of iron and steel in all its varied products. It is no wonder then, that the question of proper and suitable control for these machines is one which is commanding increased attention on the part of the steel mill engineer, who is constantly seeking to raise the overall efficiency of his plant or to increase tonnage without a corresponding increase of equipment.

Rapid strides have been made in the development of cranes and similar machines until we are now able to handle loads of two hundred tons and upwards with the same ease as fifty tons were handled a few years back, or even ten tons in the memory of a great many present. This development has not been confined to the crane as a mechanical unit but extends to all electrical apparatus necessary for its operation, such as motors, holding brakes and controllers.

With the introduction of dynamic braking and the improvement and simplification of magnetic control it would seem that we had about reached the limit of our resources in that direction. We know, however, this is not the case but there is some question as to whether the most efficient

application is being made of those appliances we now have available.

A crane may be equipped with the best designed motor obtainable, but if the control provided for its operation is not equally well designed for the service the result will be a corresponding loss in total efficiency. The same is true where a well designed controller is connected to a poorly designed motor. This condition is even more pronounced in the case of hoists where the solenoid brake, which is a part of the control system, must also be taken into account.

The object of this paper is two-fold: First—to discuss the operation of various types of overhead cranes and steel handling machines from the standpoint of efficiency in control and to attempt to show how these efficiencies may be raised by the application of proper equipment and by the proper adjustment of this equipment after installation. Second: To draw a comparison between d-c. and a-c. for crane operation and endeavor to point out the relative advantages of each and the factors to be considered in the selection of one system over the other.

GENERAL CLASSIFICATION

With the wide variety of crane application in steel mills the problem of efficient control resolves itself into an independent consideration of each individual crane, or at least each type of crane. This would require unlimited space, but for the purpose of this article a comprehensive understanding can be obtained by dividing the different types of cranes into four general groups and discussing each group. These groups would be based on the severity of service and the speed requirements which are the most important factors to be considered. The following classifications will be used:

Group 1—heavy duty—high speed.

Group 2—heavy duty—slow speed.

Group 3—light duty—high speed.

Group 4—light duty—slow speed.

By heavy or light duty is meant the frequency of operation and the continuity of service rather than the capacity of the crane or the weight of a single lift. A crane may be *large* in capacity and make heavy lifts at every operation, as

for example, some hot metal cranes, and yet be classified as light service from the standpoint of control.

By high or slow speeds is meant, not so much the ultimate running speeds as the question of whether the essential requirement is slow partial speed control, as in case of hot metal cranes or a high ultimate speed as in case of yard cranes. On this basis, and giving primary consideration to the hoist motion, steel mill cranes may be divided into the above groups as follows:

Group 1.—Loading cranes, magnet cranes, bucket cranes, soaking pit cranes.

Group 2.—Hot metal cranes, Stripper cranes, Foundry cranes.

Group 3.—Auxiliary hoists (except open hearth) Mill cranes (some types).

Group 4.—Mill cranes for handling rolls, Shop cranes, Power house cranes.

In order to avoid repetition and present the subject in the most logical manner, each motion of the crane—hoist, bridge and trolley—will be discussed independently. Other types of hoisting machines, such as open hearth chargers will be taken up under a separate heading. It is not the intention of the author to discuss ore handling equipment in any of its forms but to confine the paper to overhead cranes and steel handling machinery.

DIRECT CURRENT CONTROL

Hoist: The hoist is the most important motion of any crane and therefore requires the greatest amount of consideration. There seems to be a diversity of opinion among mill engineers as to the use of dynamic braking, although the tendency to adopt this form of control is becoming almost universal. It is the author's opinion that the objection to dynamic braking, in most cases, is due to a lack of knowledge of just what "dynamic braking" implies and for this reason, I will endeavor to give a detailed analysis of the term.

Dynamic braking is the utilization of the generator characteristics of a motor for the purpose of bringing it to a quick stop, or in the case of hoists, of limiting its speed when lowering loads of sufficient weight to overhaul the

armature. By overhauling the armature is meant its rotation due to the downward pull of the object being lowered.

When a motor has its fields excited and its armature driven by an external power, as for example its own momentum when suddenly disconnected from the line, the motor will act as a generator. If the terminals of its armature be connected to a rheostat it will hold back against its propelling force due to the generator load thus imposed and slow down at a rate proportional to this load, which is inversely proportional to the resistance in the generator circuit.

Should this external force be that of a suspended weight as in case of a hoist, the motor will also act as a generator. The result will not be an actual slow down of the armature

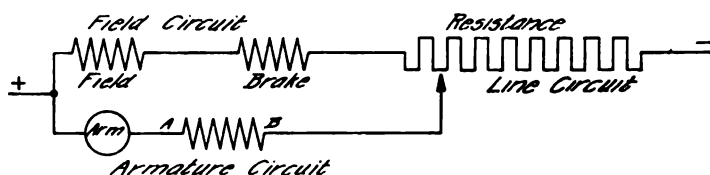


Fig. 1

since the propelling force is not diminishing in its character as in the first instance, but there will be a positive limitation of its speed. This limitation will be dependent upon the rheostatic load impressed but will not bear any direct proportion since a suspended weight which will overhaul the armature will always exert a propelling force in excess of the maximum retarding force obtainable by rheostatic adjustments.

The series wound motor is not only the most desirable for hoist work on account of its characteristics in providing high torques for heavy loads and high speed for light loads, but it also lends itself readily to dynamic braking. To understand what actually takes place in the motor circuit when dynamic braking is used for lowering we will consider first the simplest possible method of connections suitable for this service. The diagram in Figure 1, will show the lowering connection of such a controller—second point. To simplify explanations, the various current paths in this and

similar diagrams will be referred to by the terms: line circuit, field circuit and armature circuit as indicated.

First, assume that the light hook is being lowered or any load whose weight is not sufficient to overhaul the armature. When the controller is moved to the first point, the field and armature both draw power from the line and the motor operates as if it were shunt wound. The speed of the motor on this point is limited by the amount of resistance in the armature and line circuit which reduces the voltage at its terminals. As the controller is moved over the subsequent points the resistance is cut out of the line into the field circuit in successive steps and the motor accelerates to its maximum running speed.

Next, assume a condition where a load sufficiently heavy to overhaul the armature is to be lowered. When the controller is moved to the first point the load starts downward as before with field and armature both drawing power from the line. After the load receives its initial acceleration it immediately begins overhauling the armature causing the motor to act as a generator and developing a high counter e.m.f. at its terminals. This counter e.m.f. builds up very rapidly with the increasing momentum of the lowering load until it exceeds that of the impressed e.m.f. when a circulating current is set up in the generator circuit. This generator action produces a drag on the armature until the counter torque due to its own generated current (dynamic braking) balances the torque exerted by the lowering load at which time the speed will automatically adjust itself to a constant value.

The same cycle of operation takes place for each succeeding point on the controller and the resultant speed in each case will be proportional to the voltage at the armature terminals and to resultant field strength.

The generated current above referred to necessarily passes through the field windings causing the armature to supply part of its own field excitation. The amount of current taken by the field from the line will then be diminished in proportion to the amount supplied by the armature. If the lowering load be sufficiently heavy, the high resultant speed of the armature may cause the motor to generate a back e.m.f. in excess of the line voltage plus the drop across

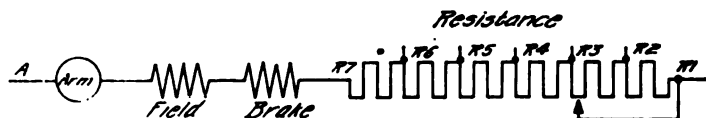


Fig. 2—(Hoisting)

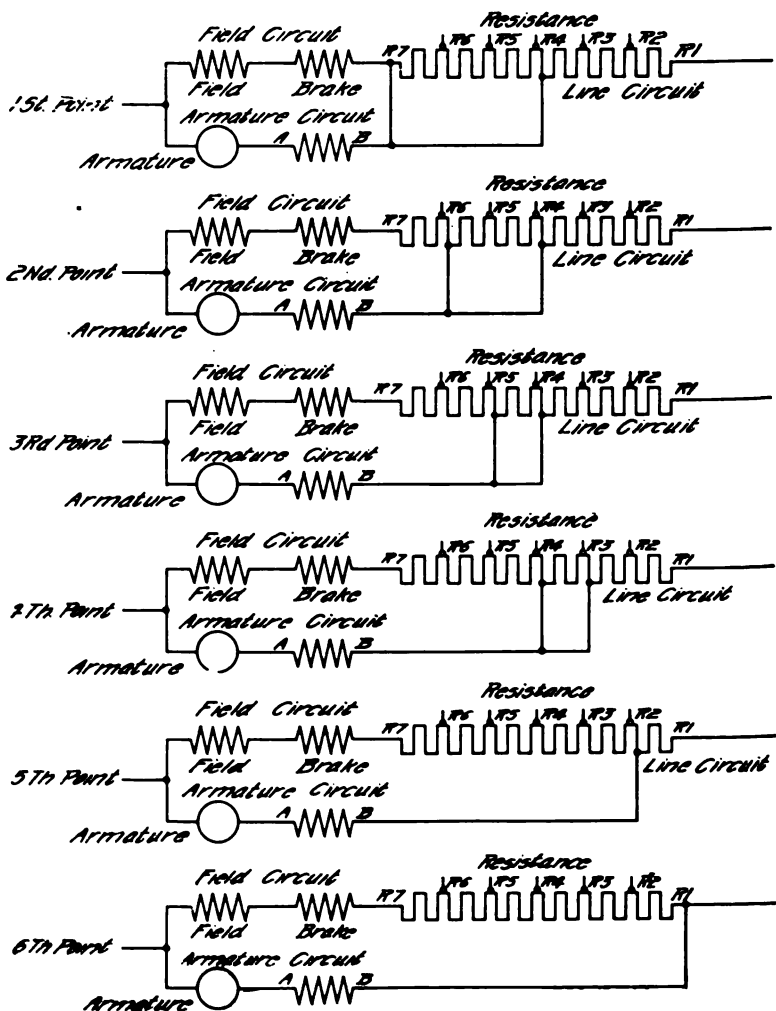


Fig. 3.—(Lowering)

the armature resistance (A-B) when power will be returned to the line.

While the above described scheme of connections will obtain successful and reliable dynamic braking, it is very inefficient from an operating standpoint and used only to illustrate the basic principle. The chief objection to this scheme is the fact that the lowering speeds are too low and the adjustments in one direction are limited by the requirements in the other. These limitations of speed control can be overcome by taking advantage of the shunt characteristics of the motor when lowering and using the field circuit to secure part of the desired speed regulation.

The scheme of connections as shown in Figures 2 and 3 has been found to give very satisfactory operation for cranes of small motor capacity (25 to 30 h.p.) and for all classes of service except where creeping speeds are essential in hoisting light loads or very high speeds are desired in lowering light loads. These points will be discussed in a later paragraph. For motors of larger capacity the same general scheme would be applicable with additional points on the controller.

The following tabulation, Table 1, will give the ohmic values for each resistance step which have been found by test to insure the most efficient operating speeds within the safe limits of a well designed motor. In order to make this tabulation applicable to motors over a wide range the values are given in terms of percentage of normal full load ohms; i. e., the ohms which would allow full load current to flow with full voltage impressed at standstill. In other words 100% ohms equals line voltage divided by full load current of the motor.

TABLE NO. 1

Rheostat Divisions	Per cent. Ohms.	
	Slow Speeds	High Speeds
R1 — R2	16	30
R2 — R3	15	51
R3 — R4	40	45
R4 — R5	34	34
R5 — R6	25	25
R6 — R7	17	17
A — B	25	25

This tabulation, together with the following speed torque curves and data on current values in the different circuits will assist in a more definite understanding of exactly what takes place in the motor during the process of lowering with dynamic braking connections.

Fig. 4.—Speed torque curves—slow speed.

Fig. 5.—Speed torque curves—high speed.

Table 2.—Current values—slow speed.

Table 3.—Current values—high speed.

Tables 2 and 3 show the current in percentages of full load which flow in the armature and field circuits and that taken from the line on all points of the controller with re-

Control Points	10% Power Torque			Zero-Torque			50% Braking Torque		
	% Amperes			% Amperes			% Amperes		
	Arm.	Field	Line	Arm.	Field	Line	Arm.	Field	Line

TABLE NO. 2

1	9	108	117	0	117	117	-44	154	110
2	10	90	100	0	97	97	-45	128	83
3	12	71	83	0	78	78	-48	104	56
4	11	80	91	0	82	82	-51	95	44
5	13	62	75	0	62	62	-61	69	8
6	13	62	75	0	62	62	-63	62	-1

TABLE NO. 3.

1	13	60	73	0	71	71	-46	112	66
2	14	53	67	0	63	63	-48	100	52
3	16	44	60	0	54	54	-51	90	39
4	14	52	66	0	58	58	-53	83	30
5	16	46	62	0	46	46	-69	54	-15
6	16	46	62	0	46	46	-82	46	-36

istance values as given under high speed, Table 1. The negative (-) sign, Tables 2 and 3 indicate current has reversed due to generator action.

These current values are given for three loads which represent average operating conditions. The columns headed "10% power torque" give the current values when lowering a light hook on a crane having a friction loss of 10% in the hoist. The columns headed "zero torque" give current values when lowering a light load whose weight is just sufficient to overcome the friction of the hoist but not to overhaul the armature. The columns headed "50% braking torque" give current values when lowering a load which would require 50% retarding torque to hold its speed to de-

sired values. This would represent full load on a crane whose overall efficiency is 70%, which is an average value.

It is interesting to note from these tabulations how the current taken from the line rapidly falls off with increased

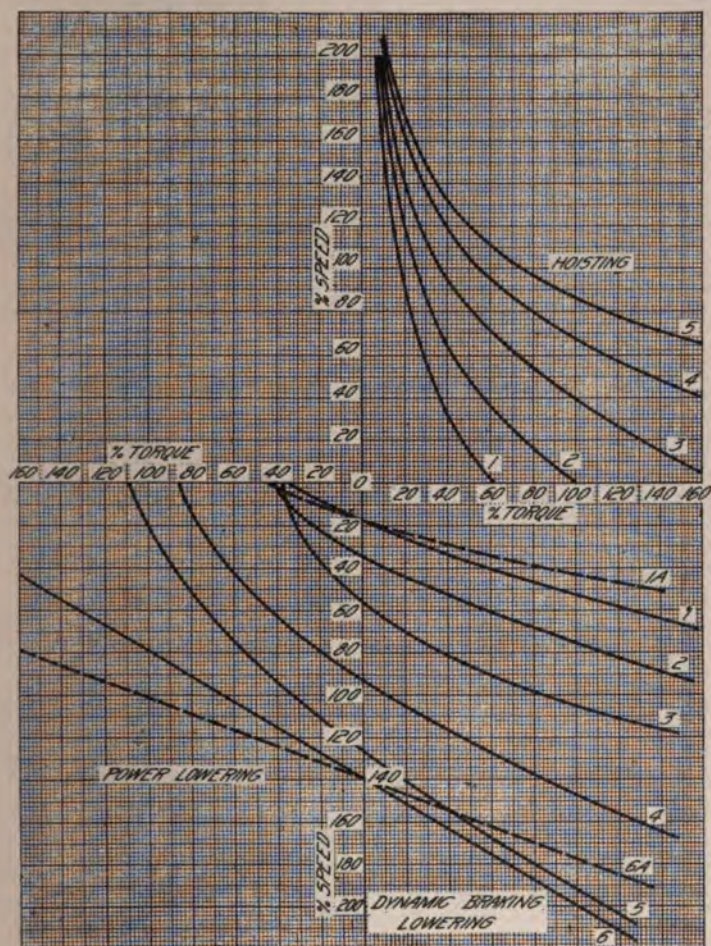


Fig. 4

speed for both slow and high speed adjustments. Referring to Table 3, it will be particularly noted that on the last two controller points the line current is actually reversed, showing that there is some return of power to the line when heavy loads are lowered at high speeds.

Adjustments: The results secured with dynamic braking depend entirely on the arrangement of the resistance steps and the adjustments of the ohmic values in each of these steps. With the scheme of connections under discus-

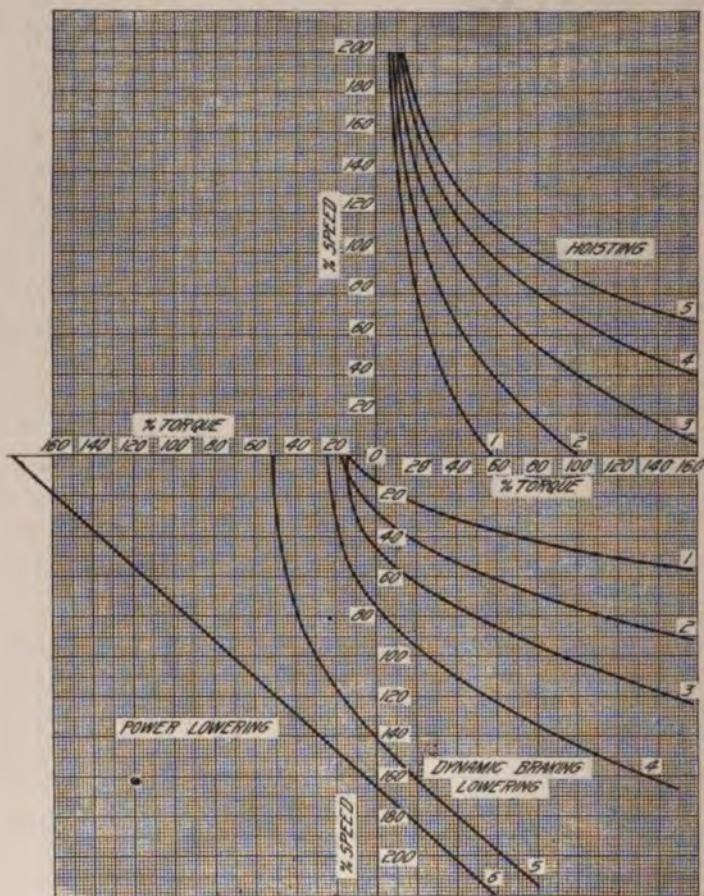


Fig. 5

sion, satisfactory speeds can be secured for all ordinary conditions by confining these adjustments to only two resistance steps which simplifies the control considerably. This can be readily seen by comparing resistance tabulations, Table 1, and speed-torque curves, Figures 4 and 5.

The most effective adjustment can be made in steps (R1-R2) and (R2-R3) which, it will be noted from connection diagrams, (Figs. 2 and 3), are only in circuit when lowering: therefore, any change in their ohmic values will only affect the speeds in lowering direction. The effect of increasing resistance in these steps would be to decrease to a very slight degree the lowering speeds on the first few points but increase them to a much greater extent on the last points and particularly the final running speed. To reduce ohmic value of these steps would of course produce the opposite results.

Any adjustment which is made on steps R3-R4, would affect both the lowering and hoisting speeds, but the former to a much greater degree than the latter. This can be seen by comparing the speed torque curves Figs. 4 and 5, where it will be noted that the hoisting curves in both instances are identical on the last four points. The only material difference is on the first point and this is so slight that its effect is not noticed in operation.

On the other hand the lowering speeds are materially affected and especially on the last or high speed points which is where the effect is most desired. As in the case of steps R1-R2 and R2-R3, any increase in the ohmic value of R3-R4, will also slightly decrease the lowering speeds on the first controller points and increase them on the last or high speed points to a greater amount.

The reason for the decrease of speeds on the first controller points with weakened field is due to the voltage across the armature being correspondingly reduced, and the effect of the latter in decreasing the speed more than offsets the effect of the former to increase it. After the controller passes the fourth point the impressed voltage on the armature is increased simultaneously with the weakening of the field, hence, the rapid increase of speeds from this point to the final running point.

It is sometimes possible to make slight adjustments on the resistance step A-B which is included in the armature circuit on all lowering points. Such adjustments, however, are to be made with extreme care and when the value which gives best results is once determined further adjustments should be avoided. The function of this step of resistance is solely to protect the motor while lowering heavy loads

against a complete short circuit, and also against injurious sparking when controller is brought quickly from full lowering to first or off-position.

The ohmic value of this resistance to afford proper protection would be influenced largely by the inductance of the generator circuit, which includes the armature, field and brake windings. The greater this inductance the less would be the resistance required and vice versa. To meet the average conditions it has been found that a resistance having an ohmic value of about three times that of the armature and brush contacts will give good results.

Reducing the ohmic value of this step would result in weakening the field and increasing the potential at the armature, thereby increasing the speeds of the motor on all positive power points and correspondingly decreasing them on all retarding or dynamic braking points. This can be seen by referring to dotted curves marked (1A) and (6A), Figure 4. These curves represent speeds on first and last controller points with all resistance values unchanged except the step A-B which is reduced to $12\frac{1}{2}\%$. It is apparent that such an adjustment is not of any particular advantage since the slight gain in speed obtained with light loads is off-set by the greater loss with heavy loads.

Increasing the ohmic value of this step would produce the opposite results to those outlined above and if the increase be very great the resultant high running speeds would approach dangerous values. This is especially true in case of a controller whose resistance steps are already laid out for high speed operation.

It is possible to secure much higher lowering speeds with very light loads by resorting to the well known means of shunting the field circuit on the last point of the controller. This will accomplish desired results where the use of the high speed point is limited entirely to the empty hook or very light loads, as any attempt to lower heavy loads will be attended with considerable danger, for the following reasons:

First: The effective retarding torque of the motor would be greatly reduced by the low field excitation required for this higher speed.

Second: The increased armature current which would be necessary to retard a heavy load under this condition might develop sufficient armature reaction to entirely overcome the field excitation and actually cause the motor to run away. This condition would correspond to a point on the "knee" of the speed torque curve of a shunt motor.

Third: Exceedingly destructive commutation might result.

Fourth: Dangerous mechanical speeds, both in the motor and gearing may be reached.

For special applications where slow or creeping speeds are required, the most effective methods to secure these are to shunt the armature, or the armature and fields, with a resistance on the first one or two points of the controller. Analyzing these two methods it will be found that by shunting the armature only, better creeping speeds can be obtained for given torque values, and with a less amount of current taken from the line. This method has one serious disadvantage in that when the controller is brought rapidly from full speed hoisting to first or off position, severe dynamic braking is produced which causes injurious sparking at the commutator and mechanical strains on the equipment.

By shunting both armature and field there is no generator action when controller is rapidly brought from full hoisting to first or off point and consequently no sparking or mechanical strains. This is because the current generated by the armature weakens the field and no reverse currents can flow.

Care should be exercised in adjusting the resistances on these points particularly in connection with ladle or hot metal cranes, where dangerous heavy loads are to be handled. For such cranes, where the maximum load is limited to a predetermined value, it is advisable to provide sufficient torque on the first point to at least sustain this maximum load. If this were not done, a load may be lifted to a given height and an attempt be made to raise it slightly further by moving controller to first point and result in an actual lowering or overhauling which would be attended with extreme danger.

Where creeping speeds are essential with light loads, as in foundry practice, it is well to caution the operator to ex-

ercise judgment and pass over these points when handling heavy loads.

THE SOLENOID BRAKE

The solenoid or holding brake may be considered as a part of the control of a hoist motor inasmuch as its circuit is handled in the controller and forms part of the control wiring. It is an essential part of the electrical equipment of the crane and its design and construction demand as much consideration as that of the motor or controller. It is an old saying that a chain is only as strong as its weakest link and this holds equally true with a chain of electrical devices operating as a unit.

The prime reason for discussing the solenoid brake in this paper is because of the bearing of its coil winding on the control circuits. For successful operation of a dynamic braking controller the solenoid brake should be designed to lift on 40% of normal full load current of motor.

The reason for this is because the field current at standstill on the first points of the controller designed for high speeds is only slightly above 40% full load. Should the brake coil require more than 40% current, it would necessitate a corresponding increase in the field excitation to insure the brake releasing, which in turn would reduce the lowering speeds on all points of the controller.

DYNAMIC VERSUS MECHANICAL BRAKING

Before the advent of dynamic braking, mechanical or load brakes were universally used as a means of controlling the lowering speeds of cranes and other forms of hoisting machinery. While there were many different designs of such brakes employed, they can all be classed under two general groups, namely, hand or foot operated brakes, and load brakes sometimes referred to as mechanical brakes.

The hand or foot operated brake usually consisted of a simple band wheel with its friction band and some scheme of mechanical connection by which the friction applied could be controlled by the operator through a lever in the cab. This lever could be either hand or foot operated. With this form of brake the speed of the lowering load would depend entirely on the operator and would attain a dangerous value

should he reduce the pressure on the lever beyond a given amount. In fact, should the operator entirely release the brake through carelessness or other cause the load would fall and possibly cause considerable damage.

The load or so-called mechanical brake differs from the hand brake in that its application is not under control of the operator. The action of this brake is to impose an additional load on the motor as the descending weight increases in speed and in this way limit its final speed to a safe value.

Since the retardation of any descending load is accompanied by an expenditure of energy, the dissipation of this energy must be taken into account in the design of the brake employed. With any form of mechanical brake this retarding energy must be dissipated in the wearing parts, principally on the surfaces of friction contact. This results in a continual depreciation of these parts requiring constant attention to keep them in satisfactory operating condition, as well as renewals at more or less frequent intervals.

With dynamic braking the energy thus expended in retarding lowering loads is converted into heat and dissipated through the rheostats without frictional wear or depreciation in any part of the hoist. There is, however, some slight additional heating of the armature and field but it has been found by actual experience that such heating is not sufficient to warrant any additional capacity in the motor over that required with mechanical brakes.

In summarizing it might be claimed that dynamic braking possesses the following advantages over mechanical braking:

FIRST: The initial cost is represented by a small difference in the controller and rheostat which amounts to much less than the cost of any good mechanical brake.

SECOND: The cost of depreciation and up-keep is practically negligible while that of a mechanical brake is always a factor in crane maintenance.

THIRD: The wear and tear on the holding brake is reduced to a minimum as the motor is practically brought to rest before this brake takes hold. Where mechanical brakes are used the holding brake is subjected to severe

shocks and does most of the work in bringing the motor to a stop.

FOURTH: It is more reliable than mechanical braking and can only fail by a break in some part of the armature circuit, and such a break would have to occur while lowering, otherwise the motor could not have been started. A mechanical brake, on the other hand, may become defective without the operator knowing it and fail at a critical time with considerable resultant damage.

FIFTH: With dynamic braking no further adjustments are necessary after the rheostats have once been adjusted to meet the load conditions of the crane. The maximum possible speed on all points with any given load can be accurately determined and there is no danger of these values being exceeded. With a mechanical brake, the maximum speed values depend entirely on the adjustment of the brake tension and this must be constantly corrected for wear, otherwise the speed would gradually increase until it attained a dangerous value.

To partially off-set the above there is at least one point in favor of mechanical over dynamic braking. That is, the motor is always operated as a series motor and in the lowering direction retains the advantages of its characteristics in providing high speeds with light loads or empty hook. These speeds are secured without the element of danger such as already pointed out in connection with dynamic braking where the field must be shunted to secure equivalent results.

Bridge and Trolley: The bridge and trolley motions of a crane present entirely different problems than that of the hoist and can be successfully operated by a simple reversing form of controller. Such a controller should provide necessary contacts for reversing the armature and sufficient resistance points to insure a smooth uniform acceleration without excessive current peaks.

The minimum number of speed control points would depend upon the size of the motor used and also upon several other factors which will be discussed under magnetic control.

There should be at least one point for plugging, that is, for limiting the current when reversing at high speeds. In

order to accomplish this the rheostat must be provided with additional ohms on the first step and the amount would vary from 10 to 50% above that required to start the motor, depending on its rating and frequency of operation.

MANUAL VERSUS MAGNETIC CONTROL

In discussing the relative merits of manual and magnetic control, there are a number of factors to be taken into consideration, some of which apply to all motions of the crane, while others are peculiar to each individual drive. Insofar as speed values are concerned, neither type has any advantage over the other, for it is possible and practicable to secure equally good results with manual control as with magnetic for any motion or class of service. As a rule a manual controller provides a greater number of accelerating points but this is no particular advantage except to introduce a greater time element between the off and full running positions and in this way reduce the high peaks incurred by rapid operation.

The elimination of the personal element of the operator by automatically limiting to a safe value the accelerating peaks as well as the high peaks when plugging, is the prime factor in favor of magnetic control with automatic acceleration. This also results in a considerable saving in wear and tear, not only on the motor and controller, but the gears and other moving parts.

The advantages gained by using magnetic control will be commensurate with the severity of the service, rather than the capacity of the crane or the weight of loads to be handled. They are also influenced by the class of help employed or in other words, the intelligence of the operators. For example, magnet or yard cranes which are in practically constant service and on which the operators are usually unskilled men, represent the worst condition to be met and magnetic control is the logical thing to use. On the other hand hot metal and foundry cranes which are less frequently in service and for which work operators of higher intelligence are employed, can be satisfactorily controlled with manual controllers, up to certain capacities.

The question of capacities is a limiting factor in manual control since it is not practical to build such equipment

in capacities above 100 h.p. for 220 volts, which voltage is standard for mill work. Such controllers would necessarily be large and cumbersome and require too much effort to operate them. This leaves no alternative but magnetic control for motors above 100 h.p.

In considering magnetic control with automatic acceleration we are again confronted with a choice of two distinct types, each possessing its own peculiar merit. One of these types employs shunt wound or voltage contactors with individual series relays while the other employs the well known and later design of series wound contactors. In general, the advantages of the latter are few as compared with the former and consist principally of simplicity in design and construction and the elimination of fine wiring and intricate interlocking circuits.

The principal advantages of the shunt contactor type of control are:

First and most important; it is adapted to applications where reduced speeds are desired and this is a necessary feature in most crane operations.

Second; it permits the operator to retard the acceleration of the motor, should it tend to be too fast for any particular work, by simply stopping the controller on the various points while coming up to speed.

The relative merits of each can be better understood by considering the influencing factors peculiar to each motion of the crane.

Hoist: For the hoist motion, shunt contactor type of control is the only one which will give satisfactory results, irrespective of whether mechanical or dynamic braking is used. The deciding factors in favor of this type control are:

First; it is essential to provide partial speed control in hoisting or lowering loads even though it is not at all times required. Second; where dynamic braking is used, the circuits must be positively interlocked and this can only be done with shunt contactors and individual relays. Third; with series contactor control, adjusted for satisfactory acceleration when hoisting heavy loads, the rate of accelerating when lowering would be so fast as to injure the motor or blow the breaker with every operation. With shunt contactors and partial speed control the acceleration could be

held to a safe value by the operator, being entirely within his control.

When dynamic braking is not used, a simple form of reversing controller with sufficient accelerating and control points, depending on the size of motor and delicacy of speeds required, will give satisfactory operation. With this form of control the light lowering speeds are inherently high enough without resorting to any shunted circuit around the field to increase them. Slow and creeping speeds can be secured in a manner already described by either shunting the armature or both the field and armature.

When dynamic braking is used, other factors enter into consideration if the personal element of the operator is to be eliminated and the controller made to give complete protection to the motor. A controller to do this must automatically govern the performance of the motor in three of its four principal operations, namely; accelerating in hoisting direction, accelerating, in lowering direction and stopping or decelerating when lowering. Automatic acceleration in either direction of rotation is the first requisite of a magnetic controller and is a feature involved in straight reverse controllers as well as those designed for dynamic braking.

With proper adjustment, automatic acceleration protects the motor and equipment against abuse by the operator in starting too rapidly in either direction by holding the current peaks to safe values. It does not, however, afford any protection to the motor against too rapid movement of the controller from the full lowering to off-position in bringing a load to rest. Such protection can only be secured with the provision of separate and distinct relays or other limiting devices by which the reverse operation of the contactors can be positively and automatically controlled in their proper sequence.

The necessity for such protection can readily be understood by a brief consideration of what takes place under such operation and the resultant effect on the motor. As previously pointed out a well designed controller adjusted to drive the motor downward at 125 to 150 per cent. full load speed, with empty hook, will permit its full rated load to lower at a speed of 175 to 215 per cent. normal. Assume such a hoist to be lowering its full rated load at a speed of 190

per cent. which represents an average condition. The field excitation must be reduced to approximately one-half to meet this condition and at the same time the counter e.m.f. generated by the armature may equal that of the impressed voltage. In moving the controller rapidly to the off-position the resistance is cut out of the generator circuit at a rate greatly in excess of that at which the speed of the armature

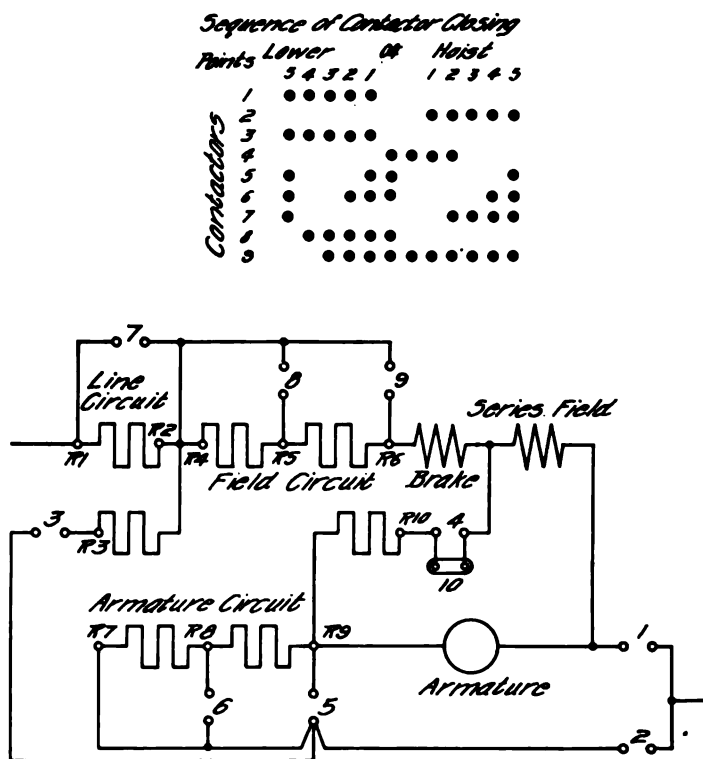


Fig. 6

falls off, thus imposing a heavy rheostatic load on the machine while its generated voltage is still high. The field of the machine immediately builds up and reaches its maximum excitation when the line circuit is broken and the excess current generated, which would normally be returned to the line, is forced through the field windings.

Since the inductive effect of a series field is very small, its excitation increases very rapidly causing the generated

voltage to correspondingly increase even though the armature is actually slowing down. It is quite possible and not unusual for this generated voltage to exceed 200% normal impressed voltage and result in extremely injurious commutation as well as excessively high currents through the motor windings.

A controller designed to overcome this difficulty by automatically governing the deceleration of the motor when lowering has been installed in the plant of the Youngstown Sheet & Tube Company and the author has made a series of tests, the results of which will serve to graphically illustrate the advantages of this feature.

The schematic connections of the controller are as show in Fig. 6, and from accompanying tabulations of controller points the sequence of operation of the various contactors can be followed. This controller was designed to provide one creeping and one slow speed point in the hoisting direction by shunting both field and armature. This eliminates injurious sparking when coming to a rapid stop from the hoist position as previously described. In addition the panel is provided with a gravity closed contactor (No. 10 on diagram) which serves to establish a dynamic braking circuit in case of failure of voltage and holds the speed of the descending load to a safe value.

Automatic acceleration in hoisting is obtained by a counter e.m.f. relay, not shown in diagram, which controls the closing of contactor No. 6 and by a series relay on the latter which controls the closing of contactor No. 5.

Automatic acceleration lowering is obtained in the same manner and by means of the same relays as in hoisting.

Automatic deceleration in returning controller quickly from full lowering to off position is obtained by series relays on contactors, 8, 9 and 6, which control the closing of contactors 9, 6 and 5 respectively in the order named.

From the diagram it will be noted that contactors 8 and 9 do not operate when hoisting, while in accelerating downward they open but do not close. Their respective series relays, therefore, do not enter into either of these operations which makes it possible to adjust the rate of deceleration independently of any other function of the controller. Furthermore, the two steps of resistance controlled by these con-

tactors can be utilized for adjusting the speeds in the lowering direction without affecting the hoisting speeds.

The controller in question is operating a 50 h.p., 220 volt, 500 r.p.m. series wound motor, geared to a double drum hoist having one hook suspended from either drum. The capacity of the crane is 15 tons and the full load hoisting speed 38 feet per minute.

The motor was tested under the following conditions of load, namely: with empty hook; with a suspended load of 5.6 tons or about 37% full load; and with a suspended load of 16 tons or about 7% overload. Simultaneous readings were taken for each point on the controller of:

A_l — current taken from the line.

A_r — current flowing in armature circuit.

A_n — current flowing in field circuit.

V_a — volts across armature terminals.

R.p.m. — speed of motor.

HOIST					LOWER				
A_l	A_n	V_a	RPM	Cont- roller Points	A_l	A_n	A_r	V_a	RPM

TABLE 4—LOAD = 16 TONS

126	98		0	1	171	115	286	54	155
137	141		-58	1-A					
320	250	32	0	2	172	-115	287	78	220
215	215	90	158	3	170	-120	290	116	330
215	215	160	160	4	75	-145	220	258	790
215	215	200	485	5	-62	-178	116	292	1080

TABLE 5—LOAD = 5.6 TONS

119	90	4	0	1	185	-25	210	26	65
259	110	62	183	2	172	-20	192	26	70
108	108	160	495	3	165	-17	182	29	80
108	108	194	612	4	110	-20	130	106	310
107	107	218	705	5	52	-60	112	246	855

TABLE 6—EMPTY HOOK

115	57	24	80	1	187	28	159	4	25
235	53	47	460	2	180	22	158	2	20
53	53	196	1080	3	174	14	160	2	0
53	53	216	1160	4	134	48	86	10	150
52	52	224	1230	5	115	7	108	110	775

The above tabulations, Tables 4, 5 and 6, give complete data for each test as indicated.

The following points are of particular interest:

First—the lowering speed with light hook was 155% full load hoisting speed.

Second—The maximum current flowing through the motor windings on any controller point regardless of load did

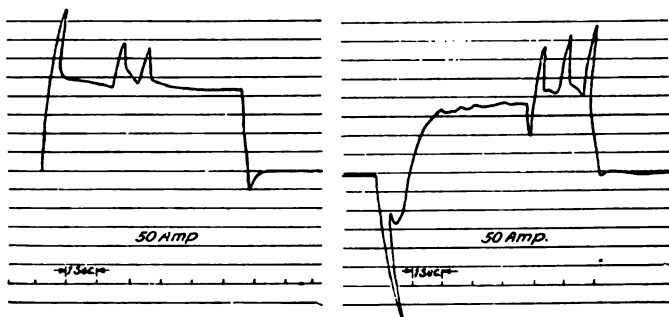


Fig. 7

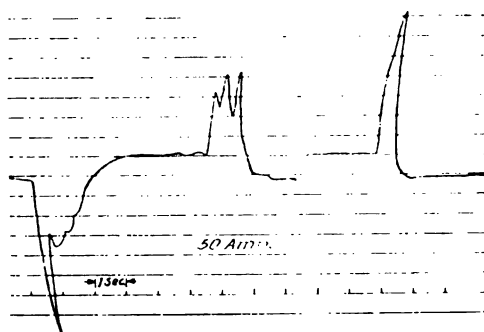


Fig. 8

not exceed 67% above full rated current (exclusive of momentary peaks.)

Third—When lowering 7% overload the speed of the motor was 216% rated full load speed which is equivalent to only 200% with normal load.

Fourth—That there was an actual return to the line of 62 amperes when lowering 7% overload at maximum speed.

Fifth—Referring to Table 4, it will be noted that two complete readings are given for the first point hoisting. The

first readings were taken when attempting to raise the load from the ground, while the second was taken after the load was in suspense and controller moved to first point. The negative reading in the speed column indicates that the load actually lowered under this condition, due to the torque on this point being too low to sustain it. This difficulty can readily be corrected by a slight adjustment in the shunted resistance circuit.

Sixth—The zero speed readings on points 2 and 3 lowering, Table 6, are due to the low torque which is required in order to hold the speeds on these points to slow values when handling heavy loads. A comparison of the speeds under loaded conditions will show how they adjust themselves to uniform values.

In order to show the automatic features of the controller, graphic ammeter curves were taken and these are reproduced in Figs 7 and 8, for conditions of load corresponding to the tabulated readings, Tables 4 and 5. In both curves, the meter was connected in the armature circuit.

Fig. 7, from right to left shows: First, automatic acceleration hoisting; Second, automatic acceleration lowering; Third, automatic deceleration in bringing the controller from the full lowering to off positions with one quick movement. The maximum peak under this latter condition was 375 amperes while the voltage across the armature attained a maximum value of 360.

Fig. 8, from right to left shows: First, automatic acceleration lowering; Second, automatic deceleration in bringing controller from full lowering to off position in one quick movement; Third, deceleration under same conditions with automatic feature eliminated. A comparison of these last two sections of the curve will show that where the motor is stopped without automatic protection the peak current attains a value of 70% higher than where such protection is provided.

Assuming that the same ratio would hold with heavier loads, the resultant peaks with 16 tons would have reached a value of 637 amperes, or 335% normal load. As the injurious effect of such a high current was apparent, no test was made to show comparative results as in case of lighter load.

Bridge: In selecting magnetic control for the bridge motion there are three things to be decided:

First: Is plugging used to stop the motor or is the motor always stopped by manually operated brakes?

Second: How many accelerating points are required?

Third: How many partial speed or hand controlled points are required?

On the bridge of most cranes, a foot operated mechanical brake is provided to bring the crane to a complete stop after power is thrown off the motor. However, it frequently happens that the operator wants to make a quick stop when he inevitably reverses the motor and "plugs" it. For this reason it is becoming universal practice to provide against the abuse of the motor under such conditions by adding a plugging point to the controller. The addition of this feature means the addition of an extra step of high resistance and one contactor which is of no service except when the motor is "plugged."

The number of automatic accelerating points which are required depends upon the size of the motor, its commutating ability and the danger of slipping the wheels. A sufficient number of points should be provided to satisfy all of these requirements. It is not advisable to use less than three points acceleration or two steps of resistance (in addition to plugging point) as this would allow an average inrush of about 140% current with peaks as high as 220%. Such high peaks might overload the motor if the service is severe and may also cause the wheels to slip.

With the use of three steps of resistance or four points acceleration, these peaks would be reduced to about 190%, while with five points acceleration the peaks would be reduced to 160% maximum which is safe for any crane motor or condition of load.

The number of hand control points to be used depends on:

First: The condition of the track, whether wet, dry, dirty or oily.

Second: The delicacy of control required for the work.

Third: External loads to be dragged around, such as cars, etc.

Fourth: Such conditions as windage, on outside or gantry cranes.

Fifth: Variable grades on the track or binding of the wheel flanges.

Sixth: Final free running speed.

Seventh: Variation in loads handled.

With the advent of the series contactors, there was a strong tendency to adopt single speed control for all bridge operations irrespective of speeds or of any factors above referred to. Experience has proven, however, that this type of control has its limitations and while there are many successful applications, the chance of failure is too great for its general adoption.

It is difficult to make any hard and fast rule by which the selection of the proper number of hand control points can be made to the best advantage but the following suggestion is offered as a guide:

Under the most favorable conditions involving perfectly good track, no delicate operations to be performed, no external loads to be dragged or windage to contend with and a final free running speed, not over 75 to 100 feet per minute, an automatic controller with series contactors and one speed point in either direction should give successful operation.

With these same favorable conditions and a final free running speed up to 300 feet per minute, an automatic controller having two control points in either direction should give successful operation.

Should the condition of the track be unfavorable an additional control point should be added to compensate for this, using two points for slow speeds and three points for high speed.

Should the delicacy of the work require slow partial speed control, additional points should be added to suit the conditions to be met.

The practice of dragging loads as well as windage, are factors difficult to overcome with magnetic control having automatic acceleration. Adjustments which would give successful operation under normal conditions of load, would cause relays to lock out and prevent acceleration with a dragging load. There are two ways to meet such conditions:

First: To provide several points hand control and set the accelerating relays at a high value to meet the maximum load imposed and trust the operator to hold the acceleration to a safe value under light loads.

Second: To eliminate automatic acceleration altogether and simply use contactors properly interlocked so that only one step of resistance is cut out at a time.

The first method is probably the better, as it would at least hold the peaks to a safer maximum value.

Eliminating windage and drag loads, which are abnormal conditions, a magnetic controller with five hand controlled points and automatic acceleration will successfully operate the bridge motion of the majority of steel mill cranes under all conditions; such a controller would be adjusted to produce the following results:

On first point—light torque to move crane without load.

On second point—sufficient torque to barely start motor with heaviest suspended load.

On third point—a torque just below that required to slip the wheels with wet track.

On fourth point—a torque just below that required to slip the wheels with dry track.

On fifth point—to bring motor to full speed.

Trolley: The problems to be considered in the control of a trolley are much the same as those described for the bridge.

With the trolley the foot operated mechanical brake is seldom if ever used and plugging must be resorted to for making quick and accurate stops. The addition of this feature requires an extra contactor and resistance step the same as for the bridge.

The automatic accelerating points would be determined on the same basis as for the bridge but will usually be less in number as the size of the motors are smaller and operating speed lower.

The principal features to consider in the selection of proper number of hand controlled points, are, condition of track, delicacy of operation, final free running speed, total length of travel, number of trolleys on same track and variation of loads handled.

When there are two trolleys on one bridge or where the span of the crane is short, it is advisable to use at least two hand controlled points and possibly three, with other conditions favorable.

On a single trolley crane with a span of about 60 feet or more, and where all other conditions are favorable, such as good track and no delicate work to perform, a single speed controller with series contactors should operate successfully, providing the final running speed does not exceed 75 feet per minute. For higher speeds an additional point should be used.

When the condition of the track is apt to be slippery or where delicate control is required, it is essential to have three or more hand control points. Taking all factors into consideration a magnetic control with four (4) accelerating points all of which are hand controlled, should successfully operate the trolley of any mill crane.

CHARGING MACHINES

Under this heading would come open hearth charging machines and slab charging machines. These machines have many things in common with cranes, but are sufficiently different to require independent consideration. Each has its own peculiar problems and therefore will be discussed separately.

Open Hearth: This machine is probably the hardest worked of any similar machine or crane in a mill and one of the most difficult to satisfactorily control, at least with any degree of protection at the motors and mechanical moving parts. This is due to the extreme variations in load conditions on practically all motions.

Unlike the crane, the hoist motion is the least to be considered, as the operation is not a straight lift but is more of a tilting motion and is obtained by means of a crank shaft geared to the motor. There are no abnormal conditions to meet as in case of the other motions which makes it comparatively simple to control.

Either a manual or magnetic controller can be applied, but owing to the severe service the latter is preferable. This be of either the shunt or series contactor type as the

travel is very short and the operation essentially one of frequent starting and stopping, therefore not requiring any partial speed control.

The bridge motion presents the hardest problem, in that it is continually required to drag loads ranging from one charging car to a train of 15 or 20 cars. These dragging loads are frequently above the rated overload capacity of the motor but must be handled when occasion demands. This operation can be successfully performed with manual control but the service is so severe as to make it undesirable.

There is no question about the superiority of magnetic control as it is the only type which will satisfactorily stand up to the work, but there is some doubt as to the use of automatic acceleration in conjunction with it. Automatic acceleration can only be made to operate under all conditions of load by adjusting the relays to meet the maximum value which would in turn sacrifice most of the protection which this feature is intended to provide. The only other alternative would be to entirely eliminate the accelerating relays and simply operate the equipment on the basis of manual control. As half a loaf is better than none at all, the former scheme will probably be more acceptable than the latter.

In either event, it would seem desirable if not imperative to provide at least two points hand control and preferably three or four with a plugging point for quick reversals. There are some installations of series contactors with one point control which have proven successful to a large degree but these are the exceptions rather than the rule.

The trolley and peel motions present problems very similar to that involved in the bridge motion but probably not quite as severe. The difficulty encountered here is in having to force the charging box into the furnace and to turn it over when the latter is more or less congested with scrap steel. The same comments made in connection with the bridge motion would also apply to the control of the trolley and peel motions.

Heating Furnaces: The machine for charging slabs into re-heating furnaces may be of the crane or overhead type or of the floor type, similar to an open hearth charger. The control for either type of this machine is quite simple since

no abnormal conditions are to be met as in the case of open hearth machines.

The bridge and trolley motions are practically identical with those of an average overhead crane and subject to the same limitations in control. Such machines would of course be classified as heavy duty, high speed, and the control previously outlined would also be applicable.

Either type of machines uses some form of tongs or gripping jaws to handle the slabs and this motion can be successfully controlled by either manual or magnetic controller. There is no particular need for partial speed control points so that a series contactor control with one speed point in either direction, should give very satisfactory results. It would be of considerable advantage and protection to the motor as well to provide overload relays on such controller, which could be set to open at a high value. Such value would have to be sufficiently high to enable the operator to secure a good grip on the slab beyond which it would trip the motor free from the line.

The swivel or revolving motion on overhead machines can also be successfully handled by manual or magnetic control but the latter is to be preferred on account of the severity of operation. Such controller may be of the series or shunt contactor type but should preferably have two or more speed control points with a plugging point which is essential as a protection to the motor in making quick stops.

ALTERNATING CURRENT CONTROL

The polyphase induction motor, generally termed the slip ring type, is the best adapted for use on cranes operated by a-c. for the reason that it develops a higher starting torque with less current and can be more easily and satisfactorily controlled than any other form of a-c. motor. The selection of suitable control for such motors on crane service, however, requires a thorough knowledge of their characteristics in order to secure the same degree of success in operation as can be secured with direct current motors. For this reason it will be advantageous to consider these characteristics in discussing the control, particularly those showing relation between speed and torque, which are directly affected by the design of the control.

Hoist: At the present writing dynamic braking for a-c. motors has not been developed to a degree which makes it practical or commercial for application to average overhead cranes such as used in steel mills. This discussion, therefore, will be limited to straight reversing controllers which have been universally adapted for crane service on all motions. These controllers may be of the manual or magnetic type and the choice would depend on the same external factors, such as severity of service, protection against careless operation, etc., as previously pointed out in connection with d-c. control.

Manual Control: The limits in design of a manual controller as to size and effort in operation are more pronounced with a-c. than with d-c. In the case of d-c. the only limiting factor is the capacity of the motor while with the a-c. the greater number of controller points which might be required must also be taken into account. With this type of motor there are two separate and distinct circuits to be handled, namely, the primary and the secondary.

The primary circuit which is used for reversing the motor does not have any effect on the number of controller points as 3-phase motors are generally used and require the same number of segments for reversing as d-c. motors. The secondary circuit, however, does affect the required number of segments and contacts and makes it impracticable to provide sufficient contact points to accelerate the motor with balanced phased connection. For this reason, most, if not all, manual controllers are designed with unbalanced phased connection; i. e., the accelerating resistance is cut out in alternate steps from each of the three (*) phases until the motor is brought to maximum running speed at which point they are balanced. The secondary winding may be short circuited or have a small permanent resistance of equal value in circuit with each phase, depending upon the work to be done.

The unbalancing of the current in the secondary circuits during acceleration does not affect the capacity of the motor required for a given duty cycle but does influence the number of control points which should be used as will be explained later.

(*) These motors have 3-phase secondary windings.

The same classification or grouping of cranes as regards speed and duty which were applied to those operated by d-c. also apply to those operated by a-c. However, there are some additional factors to be considered in the selection of a-c. control which do not enter into d-c. control and which may be summarized as follows:

First—The inherent torque required to start a-c. motors under overload condition.

Second—The starting torque required on first point of controller.

Third—The percentage of time motor will operate at reduced speed.

Fourth—The rapidity with which controller may be worked.

When starting heavy loads, which are above rated capacity, an a-c. motor requires more current input in proportion to the torque exerted than a corresponding size of direct current series wound motor. This is because the field of a series motor is over excited on overloads whereas the field excitation of an a-c. motor is not increased by such overload and may in fact be diminished if the overload become excessive. As a result the a-c. motor requires the use of more speed points to secure slow or refined speed control under high load conditions than is required for d-c. It is possible however, to obtain equally successful results with either equipment with a little practice on the part of the operator.

The torque on the first point would be limited by the speed requirements of the work to be performed. For slow speed cranes, especially where delicate operations are a factor as in foundry practice, it is desirable to limit this initial torque to 25% of full load. For high speed cranes the initial torque can be higher but should not exceed 50% in order to insure smooth acceleration at light loads.

The percentage of time the hoist will be required to operate at reduced speed influences the choice in the number of points and these should vary directly with this percentage. This is due to the fact that the unbalancing of the current in the 3-phases is inversely proportional to the number of control points employed; i. e., with fewer control points the unbalancing would be greater and result in a less equal dis-

tribution of heat in the secondary windings and in extreme cases may result in injury to the motor. With a sufficient number of control points this unbalancing of current would be minimized and the heating thereby evenly distributed.

The rapidity of operation or severity of service is a factor which requires the greatest amount of consideration, as it not only influences the number of speed points which should be used but also the effective torque delivered by the motor. If a slip ring induction motor has its secondary windings short-circuited and be connected directly to the line it would draw approximately 600% full load current and exert only 50 to 75% maximum torque. This condition is approached, if not at times met, by careless operators moving the controller too rapidly to the full running position in an attempt to gain time. The result of such action is injurious heating to the motor, or an actual delay in resetting the breaker where effective overload protection is provided. Furthermore, should the crane be loaded to its capacity the motor could not possibly be started under such conditions.

This difficulty can be successfully overcome by connecting a permanent resistance of equal ohmic value in each phase sufficient to provide a total slip of approximately 15%. This would not entirely eliminate the high peaks but would reduce them to a comparatively safe value and insure the motor starting under any load condition within its capacity. The use of such permanent resistance would naturally reduce the maximum running speed approximately 10% at full load but this reduction would be proportionately smaller at lighter loads. Should this loss in speed at heavy load be a serious disadvantage it can be compensated for by a slight change in gearing and in rare cases may require a slightly larger motor. For most classes of service this loss in speed would be a negligible quantity because reduced loads are handled a majority of the time.

High speed—heavy duty: For this class of service a controller having eight speed points should give successful service with motors of moderate size, up to 30 hp., 220 volts; for motors of larger capacity it is advisable to use 10 to 12 control points, while in either case an initial torque of 50% will be sufficiently low both for good acceleration and for

protection against plugging. It is in connection with this class of cranes that a permanent slip ring resistance as pre-

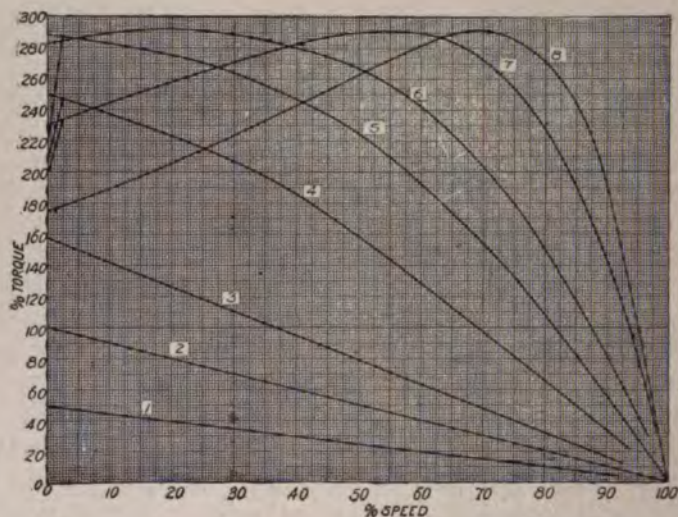


Fig. 9

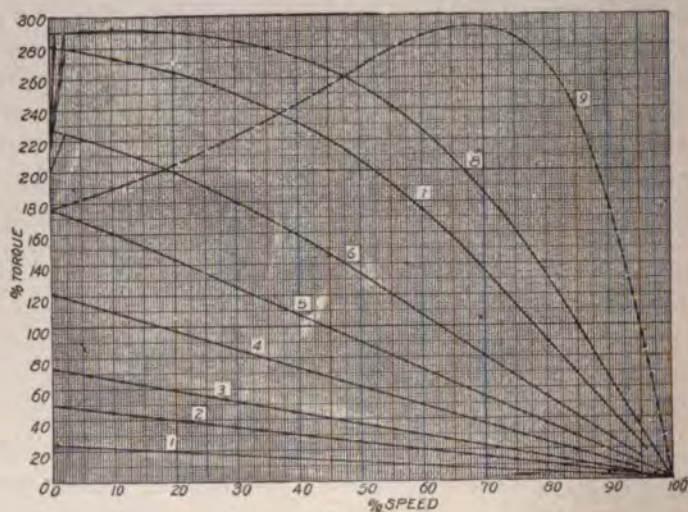


Fig. 10

viously mentioned will be most effective and should be employed.

Figures 9 and 10 show speed torque curves of a motor equipped with a controller having eight speed points, one of which is provided with a step of permanent slip resistance. A comparison of these two curves will show the advantage of this feature. Curve 9, Figure 10, represents speeds with short circuited slip rings and is added for comparative purposes only.

Slow speed—heavy duty: For this class of service the selection of speed points would depend primarily upon the refinement of control desired. Where slow speeds are required with light loads it is advisable to limit the initial tor-

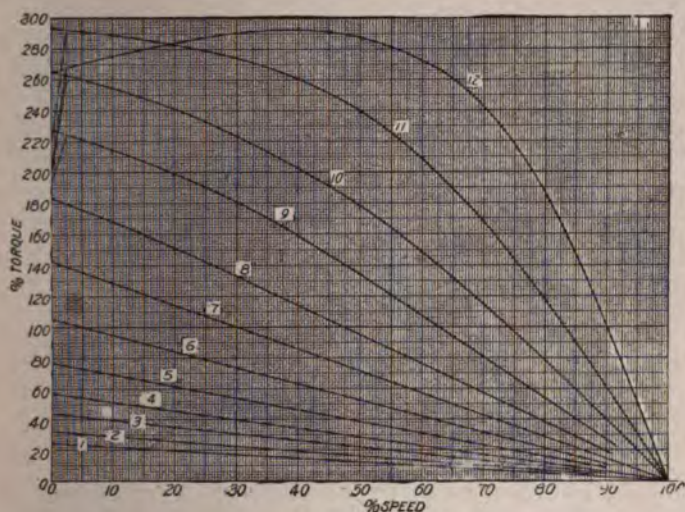


Fig. 11

que to 25% and to use a motor of such capacity that it will not be worked above 35 to 40% of its break-down torque.

For motors of moderate capacity an eight speed point controller with a permanent slip resistance will give good operating results. For motors of larger capacity a controller with 10 or 12 points should be used and this need not be provided with permanent resistance unless necessary to protect against careless or fast operation. Fig 11 shows the speed torque curves of a 12 point controller for this class of service.

High speed—light duty: For this class of service a controller having eight speed points for motors of moderate size and 10 to 12 points for motors of larger size, and designed to give an initial torque of 50% will give satisfactory results. No permanent resistance should be required except where protection against careless operation is necessary.

Slow speed—light duty: For this class of service the selection of speed points would depend upon the refinement of control desired as in the case of heavy duty cranes. For motors of moderate size an eight point controller with permanent slip resistance and designed to limit the torque to 25% full load on first point would meet most requirements.

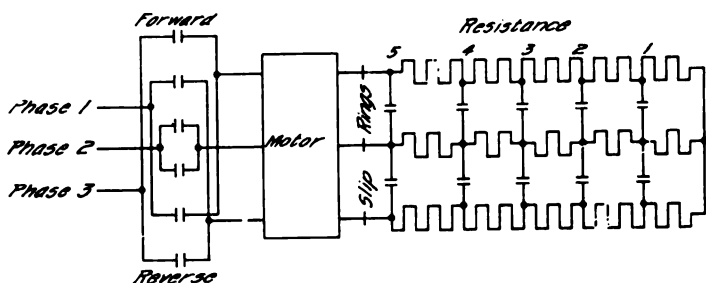


Fig. 12

However, for foundry practice it may be desirable to use 10 or 12 speed points with the same initial torque and possibly the addition of permanent slip resistance.

For motors of larger capacity 10 to 12 speed points should always be used and the initial torque limited to 25% full load. The refinement of control would determine if a permanent slip resistance would be advisable. As previously pointed out the motor should not be worked above 35 to 40% of break-down torque where refined control is essential.

Magnetic Control: The development of multi-pole contactor to operate with a-c. coils simplifies the problem of magnetic control and makes its use both practical and commercial. Contactors having 3-poles actuated with one magnet coil afford a simple means of opening and closing the primary circuits of 3-phase motors, and by the use of two such contactors mechanically interlocked a 3-phase motor may be easily reversed and at the same time entirely disconnected from the line while at rest. Contactors with 2-poles

actuated by the same magnet coil also afford a simple means of cutting out the starting resistance in the secondary circuit in equal steps thereby keeping the phases balanced on all accelerating points. This can readily be seen from the schematic diagram of connections (Fig. 12) of a controller designed to provide six speed points which will meet average conditions of hoist operations.

Keeping the phases balanced at all times and providing automatic acceleration eliminates at least two objectionable factors which enter into manual control. These are the questions of percentage of time the motor operated at reduced speeds and the rapidity of operation as affecting the starting torque. For these same reasons it is not necessary to provide as many accelerating or control points as required with manual control.

For high speed cranes a controller having approximately six accelerating points, four or five of which are hand-controlled and designed to provide an initial torque of 50% full load should give successful results under any condition of load within safe limits.

For slow speed cranes, i. e., where slow or creeping speeds are of prime importance a controller having seven or eight control points and designed for an initial torque of 25% full load should meet all conditions of operation within safe limits.

With this type of control a permanent slip resistance would not be necessary from the standpoint of starting torque or abuse of the motor but may be used to advantage in connection with slow speed operation to secure a closer refinement of control.

BRIDGE AND TROLLEY

Manual Control: The same design of controller as described for the hoist is also applicable to the bridge and trolley motions although in most cases the initial torque need not be limited to as low values. This is because the refinements in speed are not as exacting for these motions and the ultimate rate of travel is considerably higher. Controllers having eight to twelve speed points, depending upon the size of the motor, should successfully handle these motions under any condition of load within their capacity. It is also ad-

visible to use a small percentage of permanent slip resistance where the service is severe and the controllers are apt to be operated very rapidly.

This permanent resistance would not affect the final running speed of the bridge or trolley to the same extent as in the case of a hoist since the torque required under running conditions is somewhat less than that required for starting.

Magnetic Control: There is no choice in types of magnetic control for a-c. motors on bridge and trolley service as there is in connection with d-c. motors. This is due to the fact that no electrical genius has yet come forward with a series wound a-c. contactor sufficiently practical for commercial purposes. Therefore, the same type of controller as described for hoisting and shown in Figure 12 will be satisfactory for bridge and trolley service.

The external factors already discussed in connection with d-c. cranes also apply to a-c. cranes and must be given the same careful consideration in selection of suitable control. Taking into account all points covered by this discussion the question of proper control for bridge and trolley service may be briefly summarized as follows:

For high speed cranes where slow or reduced speeds are not required a controller having from 4 to 6 speed points and designed to give 50% full load torque on first point should satisfactorily operate a bridge or trolley of any reasonable capacity under all conditions.

For slow speed cranes where slow and reduced speeds are essential the number of speed points should be increased in accordance with refinement of control desired and in some particular cases it might be advisable to limit the initial starting torque to 25% full load.

COMPARISON OF D-C. AND A-C. FOR CRANE SERVICE

It is not the author's intention to draw any definite conclusions or to attempt to make any recommendations as to which system should or should not be used to summarize those factors which merit greatest consideration in making a selection. It must be born in mind as far as mechanical construction and ruggedness are concerned that both types of motors and controllers are equally reliable also that equal-

ly successful results can be obtained in the way of speed control although not with the same degree of simplicity as will be pointed out.

One of the most important points in favor of the d-c. series motor is its speed characteristics which are better adapted to this class of work and especially to the hoist motion. As already mentioned this type of motor inherently runs at a high speed with light or reduced loads which materially increases the average speed of operation and consequently the over all efficiency of the crane. On the other hand an a-c. motor will not run above its synchronous speed except when lowering overhauling loads and under such condition this higher speed is undesirable.

Therefore, in order for an a-c. motor to perform the same amount of work in a given time, i. e., make the same number of trips under varying load conditions it will be necessary to increase the rated full load speed and consequently the capacity of the motor in the same proportion. The amount of this increase would depend primarily upon the percentage of time the motor in question is operated under heavy load conditions. If this percentage is very high the increase may be only a small amount and not sufficient to warrant a motor of higher rating. If, however, the crane is one which operates at light loads a greater part of the time and on which tonnage or production depends, the increase in size of motor may reach as high as 50%. Generally speaking, therefore, a-c. motors must be of larger capacity than d-c. for crane service if an equal amount of work is to be performed.

The successful development of dynamic braking for series motors is another important factor in favor of d-c. over a-c. In addition to eliminating the necessity of a troublesome mechanical brake, dynamic braking insures a constant and positive speed on all points of the controller under any given condition of load. It is also superior to the mechanical brake from the standpoint of safety.

The torque characteristics of the d-c. motor on starting are superior to those of the a-c. polyphase motor since the latter has a definite maximum value of about 200% full load while the former is very much greater. This fact may sometimes influence the size of a motor particularly on the hoist

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motion when it is necessary to handle high overloads at infrequent intervals. For example, crane having a normal capacity of 15 tons may at times be required to lift a load of 35 or even 40 tons. This extra duty would not require any additional capacity in a d-c. series motor over that normally required but being in excess of the starting torque of an equivalent a-c. motor would necessitate an increase in size sufficient to meet this maximum demand.

In order to provide the same refinement of speed control an a-c. motor requires more points on the controller and a little additional care and practice on the part of the operator.

The wiring required for d-c. motors is somewhat less than it would be for a-c. motors of the same capacity both in respect of the number of leads and total weight of copper. The number of leads required for d-c. motors would be only 2-3 of those required for a-c. motors while the total weight of copper would probably be only from 80 to 85%. The smaller air-gap required with an a-c. motor might be considered detrimental either from the standpoint of ruggedness or power factor depending upon the design of the motor. Where ruggedness in mechanical design is of prime importance the air-gap is somewhat increased over standard practice, which in turn results in a reduction of the power factor of the motor. Where the power factor is given first consideration the air-gap must necessarily be made small at some sacrifice in mechanical design. However, in large steel plants where the crane load is a comparatively small percentage of the aggregate connected load and since it is also very intermittent in its nature the question of power factor is not one of great importance. On the other hand continuity of service is of great importance which would necessitate ruggedness in mechanical design.

Where d-c. motors are used it is necessary to either generate this form of current or to obtain it through a rotary or M-G. set from an a-c. source. Where d-c. power is generated in the prime mover there is no reason to consider a-c. for cranes as the advantages in such a case are all in favor of the former. Where central station or purchased power is used as in some modern mills this is always delivered in the form of a-c. and usually 3-phase. In such instances the se-

lection of electrical drive for the cranes would depend largely upon the following factors:-

First: The nature of connected load other than cranes.

Second: The percentage of crane load in proportion to total connected load.

Third: Continuity of crane service.

In a plant where a-c can be successfully applied for main drives and other auxiliaries, for example sheet or tin mills, and where the cranes are comparatively small in number there is no advantage in resorting to a mixed system in order to use d-c. crane equipment. The cost of installing a converting machine with its necessary switchboard, resultant loss in efficiency and depreciation, and additional complexity of power circuits would make a-c. more economical and desirable.

Where the crane load is a large percentage of the connected load and an important factor in production, and also sufficient in aggregate amount to warrant a reasonably high converting unit, the advantages of the d-c. system may offset the disadvantages of first cost, depreciation, etc. This is particularly true where the nature of the work requires refinement of control and slow or reduced speeds are essential.

Where there are a comparatively large number of cranes and all or most of them in continuous operation so that the load factor on a converting machine would be reasonably high, the advantages of d-c. would probably warrant the installation of such machines.

DISCUSSION

W. T. Snyder: Mr. Caldwell has opened up a very interesting subject, and no doubt we will have a good discussion on this paper. There are many points to be considered on this subject. I should like to hear something said on the advisability of the use of variable speed motors for crane motors and also shunt and series contactors for crane service, dynamic braking on bridge and trolley drive, operation of cranes from the floor, and many other interesting points which can be brought up.

K. H. Cederlund: The variable speed motor will, undoubtedly, be a nice thing, especially in a shop where you have to spot material and put it in lathes and different kinds of tools, and where you want a real slow speed, and then, again, on the floor where you want a fast speed, and in such combinations the variable speed motor comes in very handily.

I do not know whether it would be advisable to go into the application of two different styles of motors on practically the same crane.

L. W. Egan: Mr. Caldwell's comprehensive paper seems to give a very broad analysis of the subject of crane control, and we heartily agree with him on a number of the facts set forth in his paper, among others, that great care should attend the adjustment of lowering speeds to the danger point avoiding dangerous current surges at stopping points the advantages of shunt type contactors over the series or lookout type and the advantages of safety and flexibility of the dynamic type of braking over the load brake or mechanical type. There are some statements in Mr. Caldwell's paper, however, that we cannot reconcile with existing methods of control and upon which we differ.

Mr. Caldwell would lead us to believe that the use of the shunting method for weakening the fields to secure high speeds while lowering the light hook is attended by great danger while lowering heavy loads. This is pointed out by him on his 12th and 13th pages as against the schemes shown in Figure 3 and Figure 6 where a resistance is placed in the field circuit in the lowering direction only for weakening the fields to secure the higher speeds. In the scheme of connection shown in Figure 3, four resistance sections are used in the main motor circuit on the hoisting side. On the lowering side six sections are employed in the field circuit and one in the armature circuit, sections R1-R2-R3 being in the field circuit on lowering side only. In the scheme shown in Figure 6 three sections of resistance are used in the main motor circuit on the hoisting side. Lowering, three sections are used in the field circuit and three in the armature circuit in addition to the stationary AB section in the armature circuit. Sections R1-R2-R3 being in the field circuit, lowering side only.

In each case, the highest speed of the light hook would be limited, first by the excitation of the motor field which is fixed by the resistance in its circuit; second, by the amount of current taken from the line by the armature which is depended on the CEMF and the resistance of the stationary AB section in the armature circuit. In other words, the method is comparable with a variable speed shunt motor, of the field weakening type.

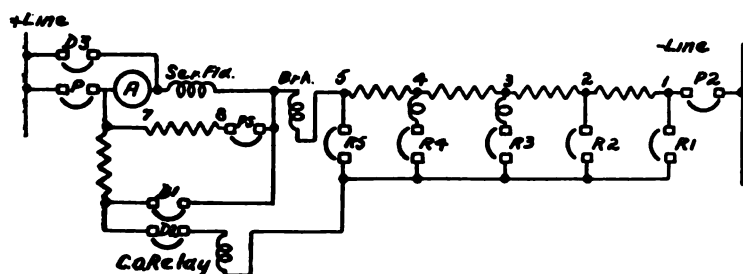


Fig. 18

	LOWERING					OFF	HOISTING				
	5	4	3	2	1		1	2	3	4	5
P1							•	•	•	•	•
P2	•	•	•	•	•		•	•	•	•	•
D1						•					
D2	•	•	•	•	•						
D3	•	•	•	•	•						
R1	•	•					•	•	•	•	•
R2		•	•					•	•	•	•
R3			•	•	•	•			•	•	•
R4				•	•	•				•	•
R5					•	•					•

Fig. 14

As the question of speed narrows down to field excitation, as pointed out by Mr. Caldwell, his 12th page, last paragraph, it would seem to be purely a matter of opinion as to whether this degree of excitation is obtained by weakening the fields with a high resistance in series with them or shunting a part of a predetermined current value around them because the ampere turns remain the same in either case. Therefore if an arbitrary speed of, say twice full load hoisting speed is required on the light hook in each case, no

greater or more dangerous speed would result when lowering the full load with a shunted field, than with a field weakened by resistance in series with it.

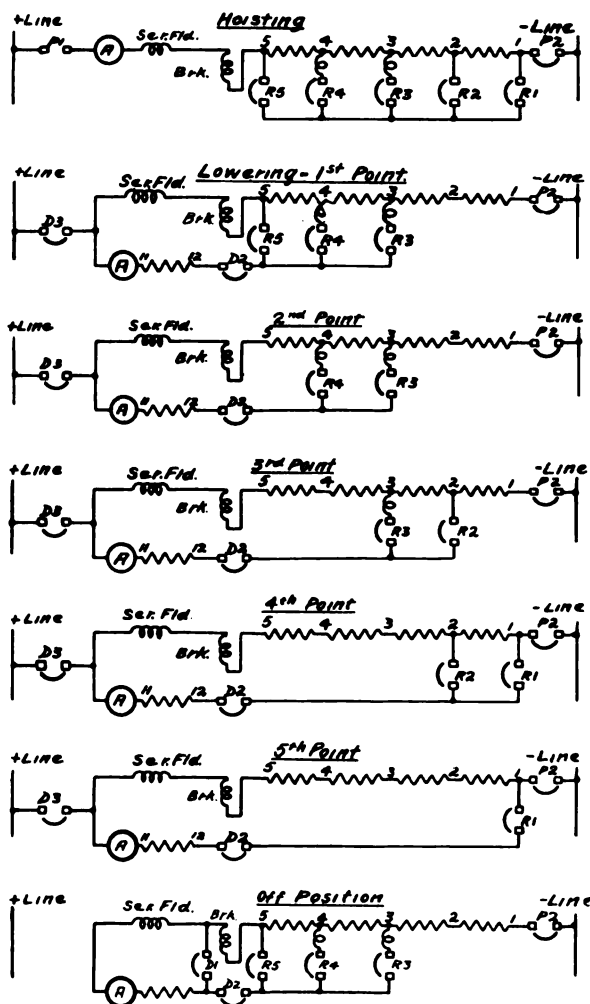


Fig. 15

At the Pittsburgh Crucible Steel Co., we have in use both these types of hoist operating successfully, the type referred to in Mr. Caldwell's paper Figure 3 being used on the earlier cranes, installed in 1912 and 1913. For the past

three years, only the shunted field type has been used. The earlier type was used on soaking pit and stripper cranes controlling 45 h.p., 490 r.p.m. motors. Also on 75-ton hot metal crane controlling 80 h.p., 490 r.p.m. motor and on 150-ton ladle crane controlling 140 h.p., 410 r.p.m. motor and a scrap-drop crane controlling 105 h.p., 470 r.p.m. motor.

Figure 13 gives the general scheme of the controller; those controlling 45 h.p. motors having five accelerating contactors, while those controlling 80, 105, and 140 h.p. motors having six accelerating contactors.

<i>Point</i>	<i>Ohms</i>
1 to 2	1.364
2 " 3	.450
3 " 4	.250
10 " 11	.400
11 " 12	.864
20 " 21	.600
21 " 22	.100

Fig 16

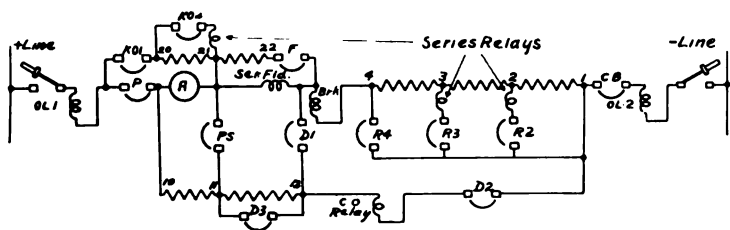


Fig. 17

Figure 14 gives the sequence of operation of the contactors.

Figure 15 gives the scheme by points.

With this method, which is practically a duplicate of that shown on Figure 3, Mr. Caldwell's paper, all resistance sections in the field circuit lowering are also used in the hoisting circuit, and all accelerating contactors lowering are also accelerating contactors hoisting. D-1 is an emergency braking contactor in the off position. C-O relay is a differential relay functioning to disconnect motor from the line when load becomes overhauling, by dropping out D-3.

P.S. is a spring closing potential switch mounted on the trolley of the ladle cranes, connected direct to the motor terminals. The control circuit of this switch is opened by an overspeed governor in the event of an excessive speed from an open in the armature circuit or other cause. It will be noted that but two series relays and one cutout relay are used on the controller for all purposes.

Table on Figure 16 gives the ohmic value of various points of a controller on a G.E. MD 105, 50 h.p., 450 r.p.m. motor.

Figure 17 gives the general scheme of the shunted field type of hoist used on all cranes during the past 3 years. Figure 18 gives the sequence of operation. Figure 19 gives the scheme by points.

	LOWERING					OFF	HOISTING				
	5	4	3	2	1		1	2	3	4	5
CB	•	•	•	•	•	•	•	•	•	•	•
P							•	•	•	•	•
KO1	•	•	•	•	•		•				
KO2	•										
D1						•					
D2	•	•	•	•	•						
D3	•										
F	•	•									
R2			•	•	•	•			•	•	•
R3				•	•	•				•	•
R4					•	•					•

Fig 18

There are three series relays and one cutout relay on this hoist. The series relay in the KO-2 circuit functions to hold out D-3 thereby preventing a rush of current through the armature circuit before a CEMF could be built up, which would prevent the brake from lifting when controller handle is moved quickly from the off position to last point lowering. This is an inherent characteristic of drum type controllers. D-1 is the emergency braking circuit on the off position. P.S. is a spring closing potential switch, functioning as a limit switch in conjunction with an overload relay. Its circuit is opened by an overtravel limit mounted on the trolley and an instant later the relay acts

or disconnecting the motor from the line. CO relay disconnects motor from the line when load becomes overhauling, that is when dynamic voltage or CEMF has reached about line voltage, when load lowers by gravity only.

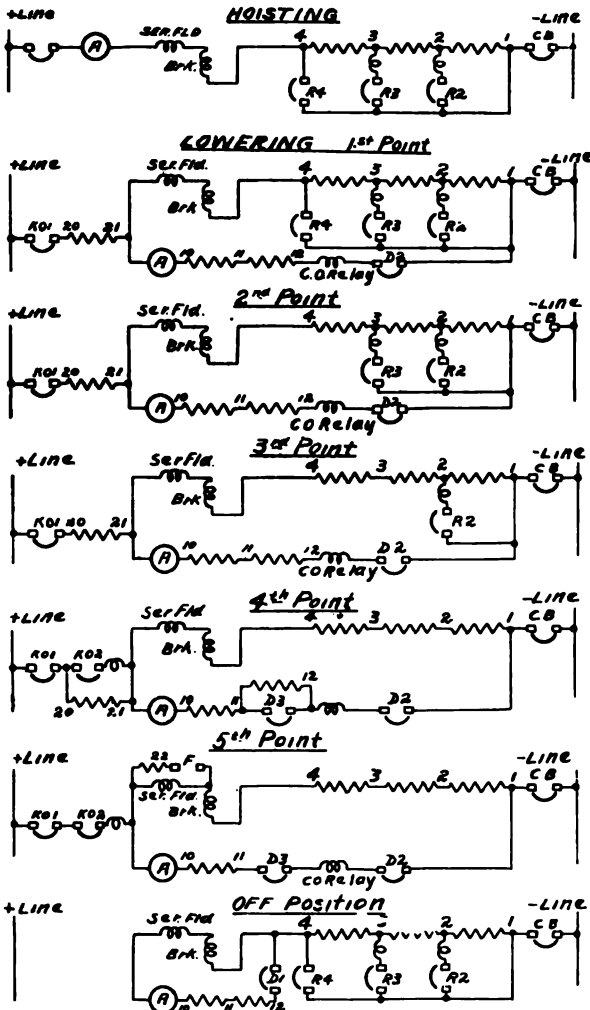


Fig. 19

This voltage does not then exceed line voltage, at any time, when controller handle is brought quickly to off position; as will be seen in Figure 20. The speed of this over-

hauling load can be varied to suit the service by dropping out certain switches.

Figure 21 gives the scheme used on mill cranes, loading cranes, and 10 and 40-ton auxiliaries of ladle cranes which is the normal operation of the controller: this drops

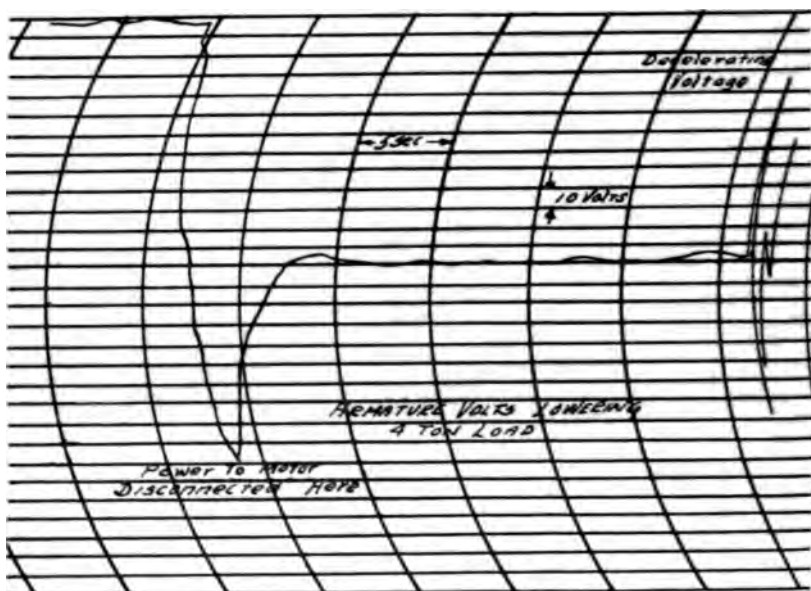


Fig. 20

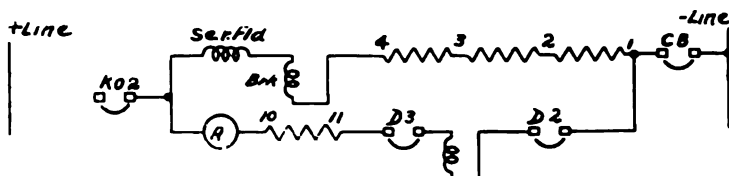


Fig. 21

out KO-1 and F contactor disconnecting motor from the line and giving full field. In the case of a 45 h.p. hoist 93% loaded, operating at 213% full-load hoisting speed at the point of cutout, would give a dynamic speed of 200% full-load hoisting speed.

Figure 22 gives the scheme used on scrap yard and billet yard cranes. This drops out only KO-1 disconnecting motor from the line leaving the field shunted, and in the above case would give dynamic speed of 240% of full load hoisting speed.

Figure 23 gives the scheme used on stripper hoist, this drops out K-O-1 and D-3 disconnecting motor from the line and inserting resistance section 11-12 in the dynamic loop

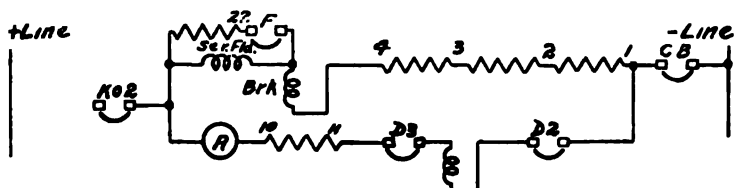


Fig. 22

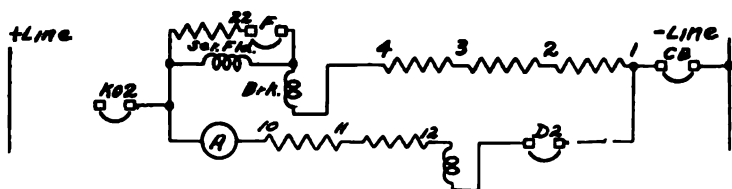


Fig. 23

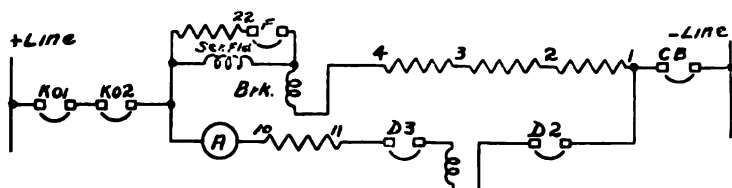


Fig. 24

and leaving the field shunted, this would give in the above case a dynamic speed of 280% of full load hoisting speed.

Figure 24 gives the scheme at instant of cutout when load has overhauled.

In any case after resistance steps and circuits have been decided upon and arranged, the action of the hoist whether loaded or light would be positive and reliable, and the action of the hoist kept within safe limits under any condition of load within the capacity of the crane: the lowering speeds

with a load as pointed out being governed by one cutout relay requiring no adjustment. This company has in use 27 of this type of hoist used on magnet cranes, mill cranes, loading cranes, ladle cranes auxiliaries stripper and bucket handling coal cranes using Brown Hoist bucket with one controller complete on the hoist line and one controller complete on the shell line. During the past three years that these hoists have been operating a load has never been dropped except by broken cable.

Without doubt all relays and adjustable apparatus for whatever purpose, operate at this convention but in steel-mill practice with varying degrees of ability in men looking after and operating the same equipment, we think the steel-mill engineers present will bear out, that if 50% of all the adjustable relays operate normally all the time, a good average has been reached and in the case of the above hoist, if CO relay, the series relay on the KO-2 circuit operate all the time, and the overload relays are set at 10 amps. per horsepower the hoist will operate normally and give all desired protection, for all loads.

F. J. Burd: The classification and groups as shown in Mr. Caldwell's paper are generally known to those familiar with the construction and application of electric overhead traveling cranes as employed by the steel mill industry. However, it is certainly an excellent move to get some of the data in the records of this Association. We will not attempt to discuss the classifications or groups named nor the description of dynamic braking. We all must be quite conversant with these subjects because all of them have received considerable attention from the members of the Association during the past few years. There are no new or novel principles in the description of dynamic braking as given in the paper under discussion.

However, the method and adjustment limitations of the resistance as described on his 11th, 12th and 13th pages do not generally apply. They would apply, however, to the scheme of connections as shown on 3rd. page. We have special reference to adjusting the last speed on the lowering side. On the 12th page certain objections are recorded against shunting the series field for obtaining a fast speed lowering a light hook. These objections are certainly cor-

rect and the dangers described would occur if the field is weakened when lowering an appreciable overhauling load with a heavy shunt around the series field.

On the other hand it is desirable to have a fair fast speed for lowering light loads and at the same time not sacrifice any other desirable features which might be limited by adjustments made to obtain the fast light load lowering speeds.

A control scheme has long been in use which accomplishes these results satisfactorily. This scheme permits shunting the series field on loads requiring power to drive downward. On overhauling loads the fields cannot be shunted, therefore dangerous lowering speeds are not obtainable.

The arrangement is entirely automatic and its operation depends on the action of the motor. The connections of this scheme are as shown in Figure 17.

There is just one remark to make about slow hoisting speeds obtained by shunting the armature. On 13th and 14th pages it is advised to caution the operators when handling heavy loads on the slow speed points. Our comment is to make the control as fool-proof as possible and not depend on instructions to operators. Usually these instructions are forgotten or they go with the first operator when another one is substituted. As a result an accident as described in the paper may occur.

The proper adjustment of the magnet brakes is indeed very important. The stroke of the magnet plunger or plate should be adjusted to move the least distance required to release the brake. After the band clears the wheel in the case of a wheel brake or the pressure relieved behind the plate in the case of a disc brake, there is nothing gained by pulling the releasing parts any further. When these parts are pulled beyond this point it only puts an extra load on the magnet in addition to an unnecessary jar which occurs when the parts are brought up against a stop post.

With the shortened stroke the magnet is made stronger by reason of the shorter air gap and in consequence the will require less adjustment to take up wear, because of the brake will be released faster and on less current. Also it increased range of the stroke.

In comparing dynamic lowering with mechanical means the former has two serious objections. If the armature circuit is opened when a heavy load is hanging on the hook the load will be dropped unless the holding brake is set quick enough to catch it. We are all quite aware of this feature. Mr. Caldwell points out that the motor could not have been started with an open in the armature circuit, therefore the open circuit would have to occur when actually lowering the load in order to drop it.

I beg to differ with him on this statement. The open circuit could occur in stationary resistance AB or at some of the controller contacts on the lowering side and still allow the load to be first hoisted and then dropped when attempting to lower it. When lowering, the series field and series brake are connected across the line independent of the armature, therefore the brake can be lifted which will release the armature with its load and thereby drop the latter.

I believe that many of the members are still endeavoring to find an electrical means for stopping the motor instantly when an open circuit occurs in the dynamic loop when lowering. Up to the present time I do not believe a successful means has been derived to meet the requirements. However, a mechanical governor is frequently used to obtain this protection. This governor is generally geared to the hoisting mechanism and acts to set the brake at a predetermined speed. Also standard crane practice is to use double collector bars for the armature circuit.

The second objection to dynamic braking is that with a heavy load hanging on the hook the initial lowering speed is liable to be quite high then fall down and then up again to a steady rate the latter being below the initial speed and the rate depending upon the controller position.

This action is due to the initial application of power to the armature and its momentarily dropping the load before sufficient retarding torque is developed by the flow of dynamic braking current. The latter does not start to materialize for an instant or so after the armature starts rotating and generally depends upon the residual magnetism of the fields.

On foundry or power house cranes, this action is more or less objectionable because it frequently interferes with accurately spotting a heavy load.

Automatic deceleration as referred to in Mr. Caldwell's paper is only obtainable by employing magnetic or semi-magnetic controllers. On the assumption that the majority of crane hoists employ magnetic control above 50 h.p. and manual types below that size, it would seem that the great number of dynamic braking manual controllers in use must be stopping the motors too fast. Also we would be led to

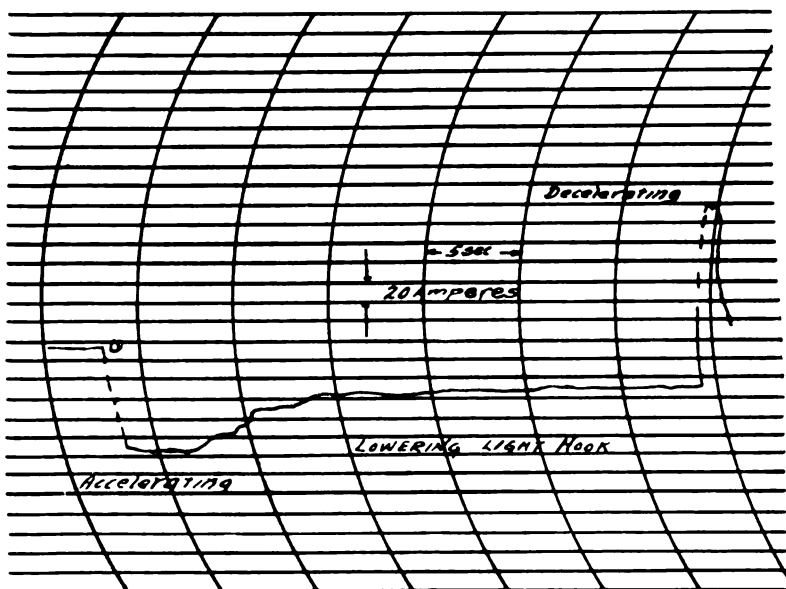


Fig. 25

believe from Mr. Caldwell's statements on his 19th page that deceleration protection is only obtainable with relays and contactors especially used for this purpose.

In order to check this statement, tests have been made on the control scheme already referred to. This scheme does not employ special decelerating contactors or relays. It will be noted that the brake coil is not included in the stopping circuit, therefore the brake is not delayed in setting by the decelerating current.

During the stopping period from the lowering side, it will be noted that the armature and series field are closed on each other through resistance 10-11-12 by contactor D-1. However, the brake does not set instantly when the controller is thrown off on account of the inherent lag of its magnetic circuit, therefore the momentum of the armature is first reduced considerably by the dynamic current and finally the brake usually sets just before the armature is stalled.

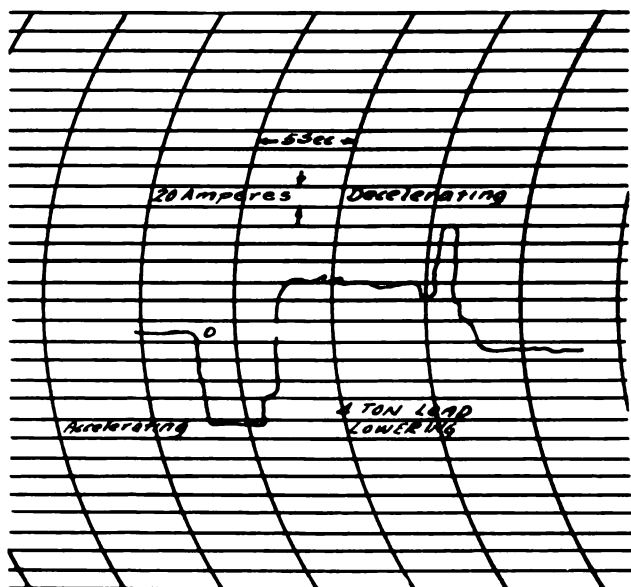


Fig. 26

The adjustments on this control at the time the following tests were made, allowed the full load to lower approximately 210% of full-load hoisting speed and a light hook to lower 166% of the same hoisting speed. It would be a simple matter, however, to increase either of these speeds without seriously affecting the other because independent adjustments are provided for both as explained before.

This control is used on a 15-ton hoist driven by a 50 h.p. series motor, the full-load hoisting speed being 25 ft. per min. The curves about to be shown were obtained with an

Esterline graphic ammeter in the armature circuit. Curves were taken with light hook, four and fourteen ton loads. The purpose of these tests are not to show accelerating or running currents as it is to indicate the current peaks that obtain by throwing the controller off quickly.

In Fig. 25 you will note that the decelerating peak is 140 amps. above the zero line. This peak is only 72% of normal current and lasted approximately one second.

Fig. 26 shows the same test lowering a four ton load. Note that the decelerating peak is only 120 amps. above zero

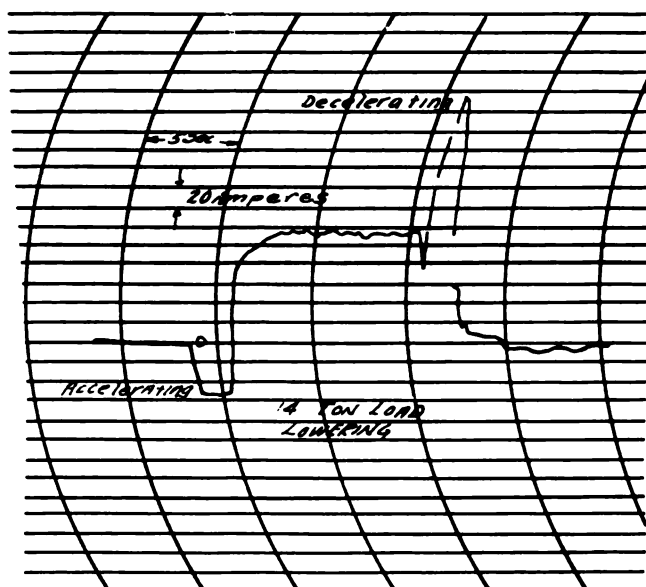


Fig. 27

which is only approximately 60% of normal full-load current and lasted approximately one second. In this instance the cutoff relay acted to disconnect the line therefore the line voltage was eliminated. In the case of the previous test shown on Curve A, the line was not disconnected because the light hook was not heavy enough to overhaul the motor.

Fig. 27 shows the same test lowering a 14-ton load. The decelerating peak is 250 amperes above zero which is only 130% of full-load current and lasted approximately one

second. The cutoff relay also disconnected the line circuit in this case.

In Fig. 28 the cutoff relay was purposely blocked in order to obtain the decelerating peak with the line connected to the motor while it was lowering the fourteen-ton load.

Note that the peak in this instance was 320 amperes and is practically instantaneous. This peak is 164% of normal-current. Also note that there was no hesitation about making the latter test. All the tests indicate currents well below those mentioned on 24th page of Mr. Caldwell's paper.

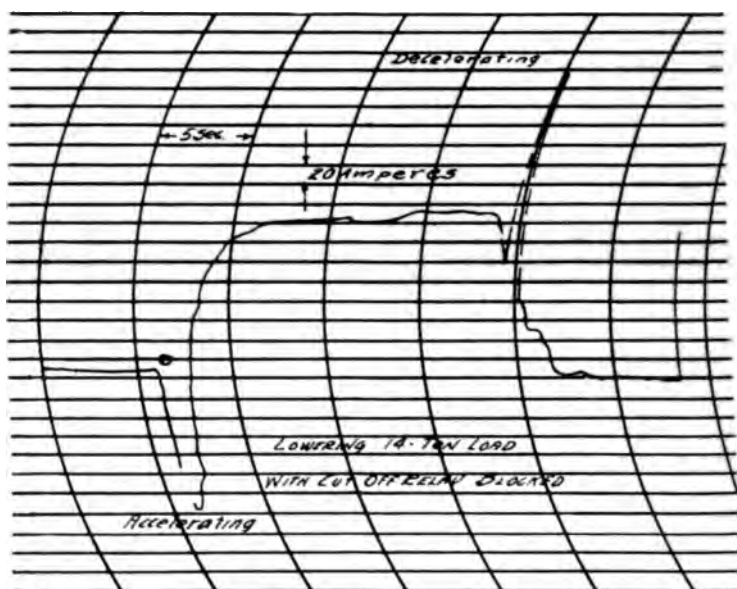


Fig. 28

On account of these decelerating peaks being seemingly low, it might be supposed that 10-11-12 resistance is comparatively high, thereby holding down the decelerating peaks. However, this can be easily checked by noting the quick stops (Note that Stops are referred to and not Peaks) shown by the curves and also by Fig. 29 and speed data.

This shows current generated by the armature when the latter is overhauled by the fourteen-ton load which was turned loose by raising the brake by hand with the controller

off. This action left the armature, series field, and resistance 10-11-12 in a closed loop.

The motor speed under this condition first raised to 700 r.p.m. and then fell back to 450 r.p.m. and then run quite steady at this figure until the load landed on the ground. Surely 450 r.p.m. could not be counted as a runaway speed and the test also indicates that resistance 10-11-12 is not abnormally high.

For making these tests we selected a crane comparable with the one described in Mr. Caldwell's paper. Both cranes

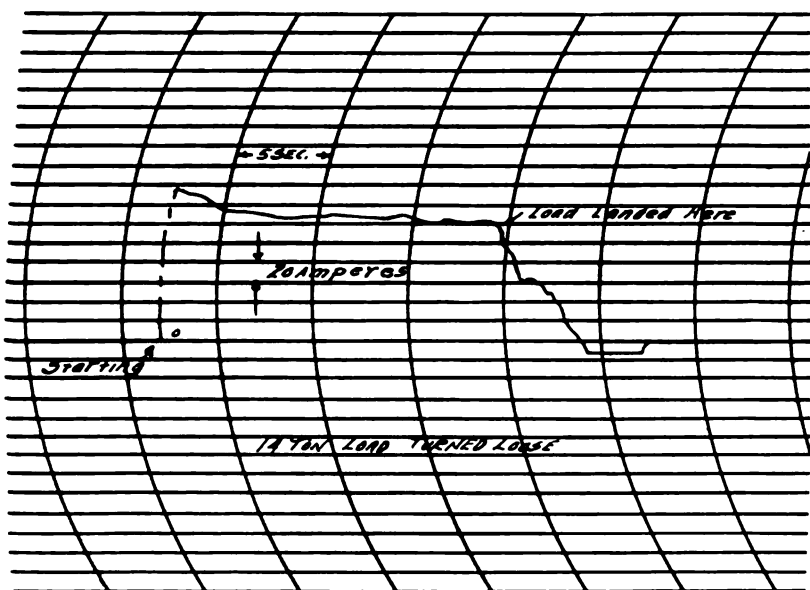


Fig. 29

are alike in capacity and size of the hoist motor. The crane we used for test was billet yard crane No. 3, Pittsburgh Crucible Steel Co., fifteen ton at 25 ft. per min. The hoist motor is GE, MD-105, 50 h.p. (30 minute rating) 196 amps., 450 r.p.m.

As indicated by the tests we obtained, we did not get the high decelerating currents as predicted by Mr. Caldwell even when stopping a fourteen-ton load.

D. M. Petty: I think Mr. Caldwell is to be congratulated on this very complete discussion of direct-current and

alternating-current motors as applied to cranes, and my particular criticism of the paper is that he did not leave any point untouched for anyone to talk about, but the discussions which have come out since Mr. Caldwell finished his paper show that my criticism is not justified.

The one remark I have to make on this subject is the fact that on any kind of crane service, motors of 50 h.p. and below, I do not feel that the complicated systems of magnetic control are necessary and think since they are not necessary, I do not feel they are desirable. The men who take care of these cranes in the repair-work in the electrical department as a general proposition have quite a few cranes to handle, and complicated systems of control are not very well fitted to getting out production if it is going to take the repairman any length of time to find trouble.

L. F. Galbreath: I do not know that I can add very much to what has been said, any more than to point out one thing in regard to heating of contacts. When automatic switches close they rebound, and draw an arc which causes the contacts to reach a very high temperature at the points where the arc strikes the metal. If the metal is a good conductor of heat and the contact is large the temperature at these points is reduced and the contacts are not nearly so liable to stick.

One advantage of manual control is that the armature can be made to start acceleration earlier than in the automatic control. This is due to the magnetic lag in the switches.

H. D. James: The very complete exposition of the subject by the author clearly brings out the advantages that could be derived if the Association of Iron & Steel Electrical Engineers could agree upon standard equipments for their various cranes. This standardization could be extended even further and made to cover many of the floor controllers.

Mr. Caldwell speaks of a-c. drum controllers of from 4 to 6 points for bridge and trolley service, and of 8-10 and 12 point controllers for hoists. For his magnetic controllers he recommends 6-7-8 points for hoisting. Another large company is offering drum controllers in 6-9-12 and 15 points and, undoubtedly, there are other variations on the market.

If you could standardize on two controllers for trolley and bridge service and two different controllers for hoists, or possibly three, when we consider magnetic contactors, considerable advantage would result from having your resistors for these controllers interchangeable. It is true that resistors can be provided with additional points so that they may be connected to a controller with four or five notches. However, it adds to the cost and complication of such resistors. I do not believe that the advantages obtained by such a small variation in the number of points is of sufficient value to pay for the complications involved. The manufacturers of controllers undoubtedly have developed apparatus with a fixed number of points, but I believe that arrangements could be made to have the various manufacturers list controllers with the points agreed upon by your Association.

Confusion often is caused in the minds of purchasing agents by various competitors arguing that they are furnishing one more point of control, and therefore should have the preference in price. This leads competition to carry in stock several controllers for each size of motor, thereby increasing the time of delivery to the purchaser for such controllers.

In specifying the resistors for crane service, specifications could be drawn up by your Association covering various kinds of service and some designating symbol given to these various resistors so that if the engineer specified Resistor No. 10 or Class 3, or by some other symbol, it would be understood, not only by your purchasing department but by the manufacturers furnishing these resistors, and you would obtain a uniform product. If you then had standardized on the number of points, the resistors purchased from manufacturing companies would be interchangeable and the variety of resistors carried in stock could, I believe, be materially reduced. Such an arrangement would also enable the manufacturers to place these resistors in their own stock, reducing the time of delivery and difficulties in ordering. It would further tend to give you a uniform price for such product.

If your Association would consider not only cranes but motors for all of your general applications; laying out the

class of service, the range of horse power and the control and resistor requirements, it is probable a much smaller variety of controllers and resistors could be used. For instance, a 7 or 8 point drum controller is applied to other motors besides crane motors. If you had two or three different resistors arranged for this particular controller, and tabulated the applications for the combination, it might result in a material reduction in the apparatus now maintained by you. I will be very glad to assist your Association in any way possible towards such a standardization.

The presentation of the subject of crane controllers by Mr. Caldwell brings out the small differences that are creeping into our applications. There is always a tendency to go into refinements and multiply the variety of apparatus to a point where the cost is out of proportion to the results obtained. On the other hand, standardization should be flexible enough to allow well considered improvements. Any proposed change, however, should be accompanied by a sufficient argument to prove its worth before it is admitted as an additional standard. If such a set of standards were adopted by your Association for steel mills it would mean that any changes in these standards would be tried out and approved before being adopted. In this way a great deal of experimental work at various mills could be eliminated.

About a year ago Mr. Henderson read a paper before your Pittsburgh Section somewhat along these same lines, and I feel it is really worthy of serious consideration, as it would be a help not only to the manufacturers, but a help to you. You are the men who are to determine what your requirements are to be, and the manufacturers are merely endeavoring to supply the apparatus as specified by you. We are glad to help you in testing your cranes, and would be glad to add our experience to yours, but you are the purchasers who are using this apparatus, and are the ones best qualified to say what requirements should be met. For one, I would be glad to assist in any way in furnishing data, but I do not believe the manufacturers want to determine this for you. We would like to have you determine it.

W. T. Snyder: We will have a meeting of the Standardization Committee in Pittsburgh in November or Decemb-

er, and we would be glad to have you present at that meeting, Mr. James.

John C. Reed: There is one scheme of dynamic braking on controllers which I wish to call attention to, and that is the very simple one of placing a series lock-out switch or relay in the lowering circuit of the straight reversing controller, causing part of the current to by-pass the armature through some resistance. This simple device I found very useful on the auxiliary hoist of ladle cranes, since it does not interfere with the rapid lowering of the hook, and at the same time it does provide a very effective means of preventing overspeeding when the hoist is loaded. This connection will stop the rapid acceleration very quickly and

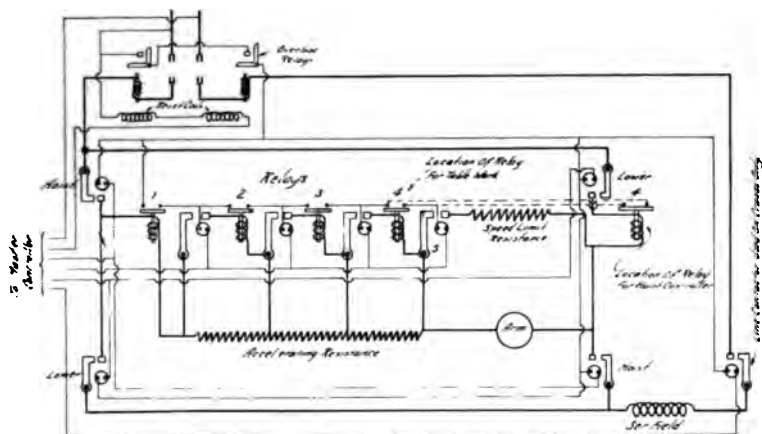


Fig. 30

cause the load to descend slowly and in order for the operator again to speed up, he must pull his controller to the off position and start over again.

Referring to the diagram, Figure 30, the series lock-out relay is connected in the lowering circuit and if the speed gets too high, the current will drop sufficiently to cause it to close, which, in turn, will close the current through the operating coil of solenoid switch "S" which shunts the slow-down resistance across the armature. A dynamic-braking circuit is thus formed which will slow down the hoist. This arrangement will prevent the bursting of armatures and I have found it very useful on soaking pit cranes, it being

possible to set the relay so that it will not interfere with the lowering of the tongs when empty but will act when holding an ingot. This same arrangement can be used successfully on table motors in which case, the relay must be located in the line so that it will work in both directions of rotation. It is also possible to use lock-out contactors which greatly simplifies the controller.

C. D. Gilpin: I think the manufacturers of cranes and charging machines will particularly welcome a paper of this sort. We receive inquiries from various steel plants regarding apparatus concerning which we get very diverse specifications as to control. One man will ask for five speed points on his bridge motion, and another man will want one point. Some do not specify anything, and we have to make a more or less intelligent guess. If you will boil things down a little it will save us a lot of trouble.

There is one point which has not been brought up, and yet it is a point which you are all familiar with, and that is the double motor drive for a crane or charger. Our company has turned out many machines of this type, in which the armatures and fields are connected in parallel, which makes the control very simple. As far as I know there has been no trouble experienced with these machines. I would like to know what the opinion of steel-mill electrical engineers is on this scheme. I have heard it criticised, but on the other hand, there are also troubles where you have separate reversers for the armatures.

There is a statement about dynamic braking in Mr. Caldwell's paper which seems to have caused a good deal of controversy. The criticism was made that separate relays for dynamic braking are not necessary or desirable. I do not know about that on small machines, but I know that on large ones they are occasionally very desirable. I think Mr. Caldwell's point was well taken.

As I understand it, you gentlemen are going to have a meeting of the Standardization Committee sometime this Fall, and if there is anything that our company can do to help, I know we will be very glad to do so. I think all of the manufacturers of these machines would also like to do what they can.

R. E. Ludwick: I agree with Mr. Gilpin and Mr. James that the crane builders have not much to say about the control equipment that goes on their cranes. In many cases, the men in the steel mills are buying their own equipment and we never see them. In other cases, where we do buy them, we are entirely dependent on the controller manufacturer to give them the right controller.

There is one instance I will refer to which embodies a very good scheme. One of the manufacturers, particularly in dynamic braking, makes us give them the size of all of our gears and pinions and the number of directions in our hoist, and they work it out then to give the proper speed control, I suppose.

There is another thing I would like to talk about, and that is your speeds. I do not believe there are any two mills which will come in with the same specifications for the same hoisting speed or bridge speed for identically the same kind of service. Take a simple case we are familiar with, and that is with a skull cracker. There are many who want to work their skull crackers at full speed—work them at 60 feet a minute, and in some cases work them at 125 feet a minute, and some think they work fast enough at 40 feet a minute. It is the same with all cranes, scrap handling cranes, bucket cranes, etc., there are few of the companies which come in with specifications giving the same speed.

I suppose that matter will come up before the Standardization Committee at its meeting Mr. James speaks of, but it would help the crane builders considerably if the mills would work to some standard speed.

R. H. McClain: There are two common types of overload relays available for crane service—the instantaneous relay and the inverse time limit relay. The purpose of this article is to discuss the proper field of application for these two types of relays.

There are four kinds of protection which an overload relay can provide under ordinary working conditions in a crane:

- 1—A short circuit.

- 2—An overload caused by broken or jammed machinery after the machinery has started.

3—Abuse of the motor due to too rapid starting.

4—Overloads due to broken or jammed machinery while in the act of starting.

Undoubtedly an instantaneous overload relay is the best thing for opening up a short-circuit because it is advantageous to remove a short-circuit from the line as quickly as possible.

In case motors are to be protected against accidents to the machinery after it is once up to speed, as, for example, collisions, hard places to get by, going around corners, or broken machinery, the instantaneous relay is preferable because just as in the case of a short-circuit, the quicker the power is shut off the better.

To protect a motor, which is controlled by a manual controller, from abuse due to too rapid starting, it is practically always necessary to use an instantaneous relay. Let us take an example of a motor which is hoisting 100% load. Let us assume that it is proper to start this motor in four seconds' time and that the peaks will be 200% load. A time limit overload relay could be used with its adjustments so arranged that it would trip out on 125% load in say ten seconds; 200% load in four seconds; 300% load in two seconds. Now, with a manual controller the operator could turn his controller on twice as quickly as was proper and draw a 300% load, but when drawing a 300% load he would get started in two seconds; therefore the relay would not prevent him from abusing the motor. If an instantaneous relay were used, set for 250% load, the power would be shut off if he should try to exceed his proper limits. If magnetic control, with current limit relays, is used, there is of course no advantage in using an overload relay at all for protecting against abusive peaks on the motor so long as the magnetic control is in good condition because the current limit relays do this. Therefore, a time limit relay is of no advantage because it would not protect the motor any differently in case current limit relays were in bad condition than it would for a manual controller, whereas the instantaneous relay would trip out immediately that the current limit relays began to skip.

When it is desired to protect a motor against burnout due to machinery which starts hard occasionally, the time

limit relay has the advantage provided magnetic control is being used. Let us assume a dead load which is normally 100% and a magnetic controller arranged to start with 200% peaks for two seconds; the time limit relay set to trip out on 150% load after five seconds. Let us suppose that the motor fails to start and that the controller permits 200% current to flow but the current limit relays will not allow any more current to flow. The time limit relay will cut off power and save the motor after five seconds, whereas if an instantaneous relay were used, it would be necessary to set this relay for about 225 or 250% current, and it would never trip out under these conditions. Consequently either the motor or the resistance would burn out unless attended to by the operator.

I would say that I believe the instantaneous overload relay is the most valuable and practical protection for crane motors. Of course complete protection will consist of a combination of some time limit overload relays and some instantaneous relays, but before going to such complications I think it is better to put plenty of margin into the motors, use instantaneous overload relays and set them at high enough value not to give annoyance due to frequent stopping on slight overloads.

When it is stuck and you try to start it, you could draw 200 per cent. overload with a magnetic controller, and yet not trip out an instantaneous relay. You could leave the motor in that condition long enough to burn it out, whereas a time relay set for low value of current would trip. That seems to be the only case where a time limit relay is advantageous.

In regard to standardization, I would like to ask what is the opinion of the people present about standardizing the number of overload relays to use on crane protective panels? Take a crane which does not have any magnetic switchboards on it; should you use two relays for motor; or one relay per motor; or one relay per motor and one main line relay; or two relays per motor; or two main line relays?

I would like to mention here the use of pump handles on controllers instead of the ordinary horizontal handle or vertical handle. If you use the pump handle, a man can have the straight up-and-down motion, he is braced to pull

a lot more than he can pull sidewise, and therefore it is easier to operate, although the work done is the same. Another advantage is that you can group the controllers, as many as six, and the operator can have full view of his work because all of the operating mechanism is behind him. I would be interested to know what some of you have to say about such a handle. It is worked on all sorts of unloading machinery, steam hoists especially.

Referring to Mr. Burd's discussion of Mr. Caldwell's paper, Mr. Burd discusses a method of shunting some resistance around the series field of the motor in order to weaken the field of the motor, and thereby speed up the motor when lowering an empty hook. Mr. Caldwell has discussed a method of inserting resistance into series with the motor field in order to weaken the field and get the same result in high speed on the motor. Under theoretically perfect conditions it makes no difference to the motor whether you weaken its field by shunting some resistances around the field, or by inserting resistance in series. The current through the field is the same in either case, and causes the same speed. However, under practical conditions which obtain in a crane, there is a certain amount of variation in resistance of trolley wires due to the motion of the carriage from one end of the crane to the other and there is a certain amount of variation in contact resistance between the shoes and the trolleys due to dust, oxide and other causes. Now, where a shunt around the field is used, this shunt will take very much more than its share of the current when there is a slight change in the shoes or trolley resistance. This will cause the field to take a correspondingly very much less amount of current than it should. On this account, the shunt is a source of more or less danger and of more or less variation from desired speed conditions. When the field is weakened by inserting resistance in series with it, a slight change in trolley resistance or contact resistance makes practically no difference at all in the strength of the current going through the field. To take the most exaggerated case where a shunted field is used and where the contact resistance becomes very high, we could have the condition of a motor running away and yet have the series brake held released by the current which is passing through the shunt

resistance. If only a series resistor were used and if the field became very weak due to an extremely high contact resistance or even an open circuit in the contact resistance, the series brake would set, or in other words, this shunt around the field adds another source of danger. Furthermore to weaken a field by shunting resistance around it, causes more current to be drawn from the line than by inserting resistance in series with the field.

I would like to ask if any actual tests have been made to show the difference in speed when the carriage is in the vicinity of the crane cab as compared with it being in the vicinity of the far end of the crane.

Another thing of very great interest in Mr. Burd's discussion is the small amount of power shown in his curve as being required to stop the load. A hasty glance at the curve shows something like 60 to 70% of full-load current as being required for less than a second to stop the load. The fly-wheel effect of the MD-105 hoist motor, which was under test, is well known and it is a simple matter to get at the fly-wheel effect of the other parts of this crane. It seems unreasonable to me that the controller could have stopped such a heavy fly-wheel effect with such a small amount of pounds-feet-seconds as are represented by Mr. Burd's curve, therefore, I am forced to the conclusion that the solenoid brake must have been called on to do the real work of stopping. This, of course, represents a condition which is to be avoided because one of the main purposes of dynamic braking on a crane hoist is to relieve the mechanical brakes of wear so that the mechanical brakes will be in good condition for holding or stopping the load in emergencies.

Mr. Burd's statement that the load will be lowered at full-speed if the solenoid brake were raised by hand when the controller handle was at the off-position is another proof of the fact that the dynamic braking did not do any of the work required for stopping the motor from full-speed down to zero-speed.

In regard to Mr. Gilpin's statement that current limiting relays are required in deceleration, I have had considerable experience with lowering heavy loads, and it has been my experience that the relays are required on heavy loads, that they should preferably be set for a lower value of cur-

rent than for accelerating. For instance, if they accelerate on 125 per cent. they should decelerate on 75 per cent. load, or something considerably less. It improves the commutation in the motor.

It does seem to me if current limit is valuable for acceleration, and saves the commutator of the motor, it would be valuable for deceleration, for the same reason. Of course, manual controllers do not have it on deceleration, neither do they have it on acceleration, and that is one of the objections to manual controllers. It is not always a vital objection, of course, because many are used successfully.

With regard to the scheme mentioned by Mr. Reed, it certainly is a simple scheme for doing the work when it is only occasionally that you have to do any dynamic braking and when that amount of dynamic braking is relatively small. You might say it avoids the necessity of going to more complicated systems, when you do not need to have them, and it works out in a lot of installations other than cranes and steel mills.

In regard to resistances for dynamic braking and controllers, as mentioned by Mr. Ludwick, who mentioned the fact that it might be advisable to go very thoroughly into the type of the crane and of the loads to be handled, that is advisable where conditions are at all special or liable to be very difficult, but I think it is very well to try to standardize on a set of resistances and control connections, so that this does not have to be done in the vast majority of cases.

I think if some of the curves mentioned in Mr. Caldwell's paper are taken proper note of, any steel-mill man knowing his conditions could pick out a controller to give the proper amount of torque, and also the proper amount of speed, after making the calculations. I refer now only to standard work.

C. T. Henderson: Mr. Caldwell points out a fact which is well known to all of us—the great advantage of the d-c. crane over the a-c. crane is the fact that on light loads it automatically speeds up. That is a very important advantage. An inherent characteristic of all dynamic braking controllers I have seen, and I think of all that have been devised, is that the lowering speed is inversely proportional to

the load; that is, when you get heavy loads they tend to go down fast and when you have a light load it tends to go down slowly. That is just the opposite of the valuable characteristic associated with the d-c. crane in hoisting.

As a result, ever since dynamic brake control began to be introduced in this country, there has been a cry for high lowering speed. The greatest criticism that has been made of the dynamic braking on d-c. cranes is the fact that the lowering speeds were not great enough, and those who adopted the dynamic brake control systems were sacrificing too much speed.

There are, as I see the situation, just two ways in which high lowering speeds can be obtained. One is by increasing the resistance included in the dynamic braking circuit, and the other by shunting the series field. The great advantage of shunting the series field, rather than increasing the resistance included in the dynamic braking circuit is that you do not disturb your adjustment for hoisting.

Every crane operator sooner or later gets his resistance so that the empty hook will just rise nicely on the first point of control in hoisting, and that is what he wants. In a great many cases if the hoisting resistance is increased with the idea of getting a high lowering speed, it may be necessary to throw the controller to the second or third point of hoisting before the hook will start. It is this fact which leads me to believe that the shunting of the series field is the preferable scheme.

Mr. McLain raises a question which to me appears to be more or less hypothetical, as to the variation of the lowering speed occasioned by the position of the crane trolley with relation to the resistance for shunting the series field. I have never made any measurements along that line, because when I have observed cranes with the idea of seeing whether such tests were desirable I have not been able to see that there was any material difference. If there was a difference it was so small as to be practically unnoticeable without the aid of instruments, and under those conditions it did not appear to me to be worth while to make the test.

The use of current limit retardation in the dynamic braking circuit certainly is more important on large motors than on small. The reason for that is quite obvious; the

larger the motor the lower the resistance of its armature and connections, and consequently the greater the possible peaks. The line of demarcation between those motors on which the automatic current limit retardation is necessary and those motors on which automatic current limit retardation is not necessary, seems to be at about 50 h.p., and that is apparently a proper limit for manually operated controllers.

It is my feeling, therefore, that while the current limit retardation by automatic means is highly desirable on motors above 50 h.p., I do not believe we need to worry about it on motors of 50 h.p. or less.

Mr. McLain brings up the question of commutation on these motors. He says if current limit acceleration is desirable that current limit retardation is equally desirable. That is true in a way, but not entirely true. The maximum peak in the dynamic braking circuit on the ordinary dynamic brake controller comes when the controller is thrown to the off position. The maximum current must be commutated, therefore, when the motor armature is revolving at relatively low speed and the potential across the motor armature is relatively small. Under these conditions the motor will successfully commute more current than when operating at higher speeds and higher e.m.f. I do not believe we need to worry as much about the dynamic braking peak as the accelerating peak, but, on the other hand, as I have already said, I believe it is desirable to provide for the limitation of these peaks on motors of what might be called relatively large capacity.

It is rather interesting to note that the pump handle control which Mr. McLain has suggested is very widely used in England and has been for several years. It is also used quite widely in Germany, and I believe it has been suggested for use in this country on many occasions, but according to my observation it never seems to have taken very well. My own personal feeling is that it has many desirable characteristics, but I do not believe it will ever take very well here.

George W. Richardson: I have tried almost all kinds of dynamic braking, from taking a 2-series field off a 4-pole machine, and putting two shunts on, using the shunt

for lowering and the series field for raising. The whole complaint, as Mr. Henderson says, is in reference to the slow speed. I took off a dynamic brake on a machine-shop crane, where we were unfortunate enough not to have auxiliary hoists, and we could not make use of dynamic brake, due to the speeds at light loads, and incorporated a scheme exactly like the one Mr. Reed has shown on the board, and we got along with that very well for that particular crane. Of course, there are some cranes where it would be necessary to have dynamic braking, that operates nearly full load all the time.

I find a considerable lot of trouble with the resistances we get with dynamic lowering, due to their not standing up so well. They send a resistance suitable for a 25-h.p. motor, and we soon burn the resistance off, and after a considerable amount of trouble, especially with the resistance, we put in a new and heavy resistance.

So far as the dynamic braking circuit allowing the armatures to run away, we thought of that, and have in some cases put in a relay to take care of the main line circuit to throw it off the moment anything breaks in the dynamic circuit.

There are a number of cranes which we have on which we would not put a dynamic brake, some are working nicely without it. The first application of dynamic braking we had many years ago in our repair shop. We did not have any brakes to use. We were racing the commutators and tearing them apart, and after we put in a little resistance in the old type control it eliminated that trouble. Those conditions were all right for light loads on small hoists that we did not have to hoist very high.

I had one peculiar case where we used a dynamic brake along with a load brake, and it worked very nice. I suppose it is due to the load brake being so much worn it allows it to slip, and we do not have any trouble. In the particular crane I am speaking of I have had some heavy loads put on it, a 25-ton crane, and we handle those loads very neatly, not having any other but the one series electric brake on it.

T. E. Tynes: Mr. Snyder asked a question in regard to controlling cranes on floors. We have one 10-ton crane operating, which is controlled from the floor by automatic

control and dynamic braking, and so arranged that if the operator should stumble or faint, the crane is automatically shut down and brought to a stop. That crane is of 10-ton capacity, but the principle involved would apply to a 25-ton or a 50-ton or a 100-ton crane, so far as I can see, and I have no hesitation in saying you can control these large size cranes efficiently and safely from the floor.

F. R. Fishback: In what I am going to say, I would rather not have it taken as a criticism of anything said in the discussion this afternoon, but I cannot help thinking of what Judge Olson told us last night about studying people's characteristics in order to get a line on their conduct. If your Standardization Committee is going to draw up rules for selecting speed-points, motor design, number of overloads on a crane switchboard, etc., my suggestion would be to form a Committee of Psychological Experts to standardize men's minds first. Until you do that, you cannot standardize on the number of speed-points, on the number of overload relays, or similar questions.

I will ask any man here today, if our Committee should say that a 25-h.p. motor should have six speed-points. I can almost hear some of these men saying, "That is too many, and I will not have that many in my mill, and I am going to cut it down to three or four." If the manufacturers should follow this procedure and give what the Standardization Committee asked for in the matter of speed-points, arrangement of motor fields, etc., I think I would be tempted to go into business for myself, and I think I could deal with a lot of the men here this afternoon and sell them what they want. Each man in each shop has a different condition from the man in the other shop. I do not see how the manufacturers are going to get away from that state of mind of the man who is buying the apparatus. We all have seen this tendency in the question of number of speed-points. I have seen specifications that called for 100-h.p. motors with speed-points all the way from 2 to 6, and each man thinks he is right. The first thing that the Standardization Committee must do is to standardize men's minds rather than the speeds they shall use.

W. T. Snyder: In answer to Mr. Fishback, I will say if our Standardization Committee has the 80 per cent recom-

mentation of the requirements of the steel industry, the manufacturers would be safe in adopting that as a standard, and put an extra price on anything special, and there would be very little that was special asked for.

Paul Caldwell: The first point Mr. Burd brought out referred to the shunting of the series field for securing high speeds when lowering light loads with a dynamic braking hoist controller and called attention to the apparent fact that according to my statements I did not believe in making a controller fool-proof. To support his contention, he showed a diagram of an elaborate magnetic controller by which scheme you can provide a shunted circuit around the series field to weaken same when lowering light loads, and have this circuit automatically opened to provide a stronger field when lowering a heavy load. Mr. Burd makes particular reference to 12th, 13th and 14th pages of my paper but fails to note that they refer entirely to manually operated controllers, as plainly stated by the heading under which these statements occur. In other words he is comparing two entirely different devices, which bear no relation to each other from an operating standpoint. If he can show me how he can accomplish this automatic protection with a manual controller as referred to in my paper, I would certainly be glad to have him do so. I happen to know of manual type controllers which are on the market at this time that provide for shunting the field circuit and which of course have no automatic means of opening this shunt when heavy loads are handled.

As to Mr. Burd's scheme of dynamic braking employing the use of a cut-out relay with a shunt around the series field, this is very old and well known. Some of us used it when we could not devise any other scheme of control that would meet satisfactory operating conditions without it. However, there are other and safer ways developed to accomplish the same results and I think my paper shows one way which does so without resorting to the dangerous practice of shunting the field.

In regard to the opening of the A-B circuit (Fig. 3) allowing the load to drop, I think my paper covered that point, but perhaps not as clearly as it might. I assume that double connectors would be used in this circuit which I believe

is standard practice and therefore did not make particular mention of it. In fact the connection diagram referred to shows double connectors from one side of the armature to the rheostat, which forms part of the field as well as armature circuit. Inasmuch as one side of the line when hoisting, connects to the armature at point "A", any open in the circuit between the armature and field would have to occur while lowering, otherwise there would have been no circuit to hoist the load.

As regards Mr. Burd's statement that it would be possible with an open in the armature circuit, to first hoist the load and then have it drop when lowering, I would say this sounds very improbable for the solenoid brake would set as the controller passed through the off position.

With reference to the deceleration of the load by the method which Mr. Burd discussed, he showed some curves of tests and other data, which looked and sounded very well, but there are at least two statements I cannot gibe together. Mr. Burd brings out the point that the solenoid brake is left out of the dynamic braking circuit, and therefore the brake is not delayed in setting by the decelerating current. In almost the next breath he refers to the inherent lag of the magnetic circuit of the brake holding it released until the dynamic current has more or less stopped the momentum of the armature and the brake usually sets just before the armature is stalled.

In a series of curves he shows graphic ammeter readings taken while lowering different loads on the 15-ton crane, driven by 50 h.p. motor and calls attention to the small percentages of current input to the motor required to bring it to rest. He refers particularly to a 14-ton load being brought to a stop in one second, with a single peak of 165% full-load current, and according to the figures previously given, that load must have lowered at a speed of nearly 210 per cent. full load. I happen to know that the motor he refers to requires full-load torque nearly one second to stop its momentum at this speed. In his case he had full load as well as double speed, and how he could have stopped it in the time stated, except by means of the solenoid brake is a question. The work must have been put on the solenoid

brake and other mechanical parts instead of where it should be put—on the motor itself.

Mr. Petty made a statement regarding magnetic controllers not being necessary on motors of 50 h.p. and below. I must disagree with Mr. Petty, for in my opinion there are as many crane motors of 50 h.p. capacity and below where magnetic control should be used, as above 50 h.p. The choice between magnetic and manual control cannot be properly based on the capacity of the crane or on the loads which the crane is required to lift.

No crane is reversed or "plugged" more frequently than a yard or magnet crane and yet they are seldom equipped with motors above 50 h.p. It is as a protection against such severe operation and abuse that the magnetic controller finds its greatest application, so why eliminate its use from cranes that operate 24 hours a day and handle the greatest amount of material in your plant, and apply it to other cranes, which, while larger in capacity, probably work only 50 per cent. of the time and under less severe conditions?

I agree with the remarks of both Mr. James and Mr. Fishback regarding standardization and hope something will come of this new committee.

With reference to Mr. Ludwick's remarks, regarding requests for crane data, we very often ask for this data and find many engineers do not think it necessary. However, if they would attempt to design a controller, especially for hoisting service, and determine exactly what results will be secured in the way of speed-torque curves, they would soon see the necessity of having this information. As Mr. McLain brought out in his remarks, there is a sufficient number of standard cranes from which most of this data can be completed without going to the crane builder for additional information, but in case of special types of cranes, it becomes necessary to ask for specific information for each crane.

Mr. Henderson made reference to the disadvantages of dynamic braking being due to the fact that it provided slow speeds with light loads and high speeds with heavy loads, and therefore necessitated some sacrifice in speed. This was true to a considerable extent when the first controllers

were designed for dynamic braking, but has been overcome to a satisfactory degree by improvements in the design of these controllers.

Mr. Henderson mentions two methods of overcoming this objection, one of which employs the shunted circuit around the series field as described by Mr. Burd. I wish to take exception to his statement, however, that this scheme has any advantage over other schemes, in that it permits of speed adjustments in the lowering direction, without disturbing the adjustments in the hoisting direction. The scheme of connections shown in my paper do not employ any shunting of the fields but do permit of independent adjustments in the hoisting and lowering directions, and I have also shown how these adjustments can satisfactorily be made. This scheme goes still further and provides for an adjustment in the rate of stopping or decelerating, which is also independent of the rate of acceleration in either the hoisting or lowering direction.

Mr. Richardson brought up the same objection to dynamic braking controllers on account of the slow speeds in lowering with empty hook. It is possible he has had these controllers a considerable length of time, for when dynamic braking was first developed, the lowering speeds were not very high. With later improvements it is now possible to secure light lowering speeds of about 150 to 160 per cent. full load without attaining a dangerous speed when lowering heavy loads.

When the percentage of time a crane lowers its empty hook is considered, it will be found that there is very little loss during a full day's operation. At most, the empty hook could not be lowered more than 25 per cent. of the working time and in actual practice would not exceed 10 or 15 per cent. With the small additional increase in speed that would be possible without dynamic braking it can be seen that the time lost due to its use is practically negligible.

Paul Caldwell (by letter): I desire to add the following remarks to those made by me in conclusion of my paper presented at Chicago.

In the course of his discussion, Mr. Burd presented the results of some tests which he states were made for the purpose of checking those given in my paper in order to show

that my contentions regarding the value of automatic deceleration or protection to the motor when bringing a lowering load to a stop, were misleading. He claims to have secured much better results with a scheme of connections which did not provide such automatic protection, but after carefully analyzing his data, I am forced to the conclusion that he has been mis-led by his own figures. It is evident that these figures were based on the assumption that since the two cranes were of the same capacity and equipped with motors of the same horse-power, the results secured would necessarily be comparative. He failed, however, to take into account the wide difference in hoisting speeds, which directly affects the actual power required, and to make proper allowance, for this difference in computing the final results.

The crane which Mr. Burd tested had a hoisting speed of twenty-five feet per minute with full load, whereas the one referred to in the paper had a speed of thirty-eight feet per minute under same conditions. Since the power required to hoist a given load is directly proportional to the hoisting speed and since the rated capacity is the same in each case, it follows that the power required to hoist full load would be in the ratio of 25 to 38 for the two cranes, (assuming friction losses to be equal).

By referring to table No. 4 in the paper, it can readily be seen that the power required to hoist 15 tons at 38 feet per minute was almost exactly 50 h.p. and therefore, the actual power required to hoist the same load at 25 feet per minute is practically 33 h.p. This is the value which Mr. Burd should have used as a basis for computing the percentages of his peak currents, instead of the name-plate rating of the motor which not only means nothing but shows that the crane tested was overmotored exactly 51 per cent.

As a matter of further comparison I will select Mr. Burd's data for a load of 14 tons as represented by Fig. 28, and my own data for a load of 16 tons as represented by Fig. 7, and reduce them to a basis of full load or 15 tons. Such a slight adjustment in the figures should not introduce any appreciable error in the final result.

First, reducing Mr. Burd's figures as given in his data to the basis of actual power required to hoist this load of 14 tons, we find that his peak of 320 amperes which he

states was only 164 per cent. full load was actually 245 per cent. Therefore on a proportionate basis the peak with 15 tons would be 343 amperes or 264 per cent full load current.

Second, reducing the peak given in the paper in the same proportionate basis, the actual maximum peak with 15 tons would be reduced to 351 amperes or only 180 per cent. full load current.

In other words, the peaks produced by Mr. Burd's scheme of connections instead of being lower as pointed out by him are actually higher, and in case of full load, this difference amounts to approximately 83 per cent. It is interesting to note that these figures check very closely with those given in the paper in connection with Fig. 8, where the difference in peaks with and without automatic deceleration were found to be about 70 per cent.

It is quite apparent therefore, that Mr. Burd's own curves and the results of his extensive tests merely confirm my own investigations along the same line, and serve to strengthen my contentions regarding the value of automatic deceleration in bringing a hoist motor to rest from its lowering direction.

Another interesting point in regard to these same tests is the comparative time required for bringing the load to rest. Referring to the curves in question it will be seen that the 16 ton load lowering at 216 per cent. speed was stopped in $2\frac{1}{2}$ seconds, while the 14-ton load lowering at 210 per cent speed required $3\frac{1}{2}$ seconds, which is 40 per cent. greater. This increase in time with higher current peak, can be accounted for by Mr. Burd's own statement to the effect that when the brake was raised with the controllers in the off-position, and full load on the hook, the hoist lowered at full load speed. This simply shows that dynamic braking is only effective to reduce the speed to full load and that the solenoid brake is forced to bring the load from this speed to rest.

Another point to which Mr. Burd calls particular attention is the fact that in his scheme of connections the brake coil is not included in the dynamic circuit while it is included in the connections given in the paper—Fig. 6. I, too, desire to place particular emphasis on the same point as it is one of the most important differences between the two

schemes of control. To be more correct, however, this coil is included in the dynamic circuit only during the period of deceleration and is cut out the instant the last decelerating contactor closes, which occurs when the speed has been reduced to a very low value, approximately 15 to 20 per cent. full load.

There are several distinct advantages to be gained by connecting the brake coil in this manner.

First: It puts all the work of stopping the load on the motor, which is the desired result when dynamic braking is used to perform the function of the old mechanical or load brake.

Second: It reduces the wear and tear on the solenoid brake to a minimum since it is only required to perform the service for which it is intended, namely, that of holding brake to hold the load when same is not in motion.

Third: It adds to the safety of the crane by conserving the wear on the solenoid brake.

Fourth: It reduces the wear and tear on the gearing and other mechanical parts by eliminating the severe shock which is always attendant by the quick setting of the solenoid brake, while the motor is running at a high rate of speed.

Fifth: It eliminates accidents due to the unequal time element in the setting of the brakes where two motors are used, each driving a separate drum and the drums geared together, as in case of hot metal or bucket handling cranes. Assume that such a crane is lowering its full rated load and the brakes are free to set the instant the controller is brought to the off position and the operator attempts to make a quick stop. Should one brake take hold before the other (and it is a very likely occurrence) the result would be a sudden and severe retardation of the motor driving one drum while the continued momentum of the other motor and intermediate gearing would cause the second drum to start a rotating movement about the first one as an axis. This action often results in the elongation of the bearing cap bolts and has been known to actually break off the bearing caps and allow the drum to raise completely out of its bearings.

Such accidents can only be effectively overcome by designing the controller to prevent the setting of the brakes until the motor is brought nearly to rest when the unbalanced torque would be insufficient to do any damage even though the brakes did not operate simultaneously. The use of automatic deceleration as explained in the paper insures against such accidents.

OPERATING CHARACTERISTICS OF AN ELECTRIC REVERSING BLOOMING MILL

By E. S. JEFFERIES

It has only been within the last three years that American Rolling Mill Engineers have given serious consideration to adapting the Electric drive to the two-high blooming mill, although this system of driving a reversing mill has been in operation in Europe for over ten years. It is the purpose of this paper to take up a few of the operating characteristics of a 34-inch reversing blooming mill in the Steel Company of Canada's Works at Hamilton, Ontario.

The Ilgner system, which is used to drive this mill, employs a heavy fly-wheel in conjunction with a motor-generator set and a device that will enable the fly-wheel to give up some of its stored energy when the demand for power is great, thus reducing the peaks, which would otherwise have to be furnished by the motor. During idle periods such as between ingots and passes, the motor speeds up the fly-wheel and thus replaces its rotative energy. It is necessary to interpose such a flywheel between the source of power supply and the mill motor in order that the mill may be started, stopped, reversed and controlled in speed with a minimum loss of time; to accommodate wide variations in power and to permit of a very simple means of control.

DESCRIPTION OF THE ILGNER SYSTEM

The Ilgner set consists of a fly-wheel motor-generator set, slip regulator, an exciter, a reversing motor, and control apparatus. The motor generator set consists of an 1800-h.p., 2200-volt, 3-phase wound rotor induction motor; a 50-ton fly-wheel and two 1200-kw., 600-volt d-c. generators, all mounted on a common shaft. The slip regulator or water

1

which is lost in steam driven mills, is saved in an electric driven mill in this manner. The time of acceleration of the mill motor from practically zero to full speed, is only one and one-half seconds during some of the short passes, and of course lengthens out for the long passes.

Fig. 2. shows the efficiency of the Ilgner set taken as a unit, based on approximately 1200 tons of finished $3\frac{1}{2} \times 4$ inch billets, all data being taken from Curves "A" and "D"

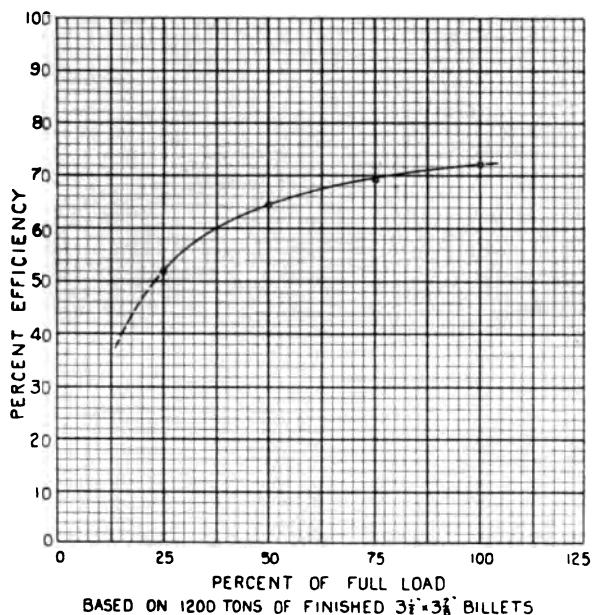


Fig. 2

in Fig. 1. The input as shown by Curve "A" being 139,043 kilowatt seconds, which gives 19.81 kw-hrs. per ton of steel and an average input of 959 kw. One-hundred per cent. load of the efficiency curve is based on rolling at this rate; the out-put was obtained by plotting a curve parallel to Curve "D", which allows for the inefficiency of the motor. It is interesting to note how close the above 19.81 kw. hours per ton agrees with Curve in Fig 3 taken from actual operating conditions. This indicates that the efficiency curve is fairly reliable under the conditions assumed, which

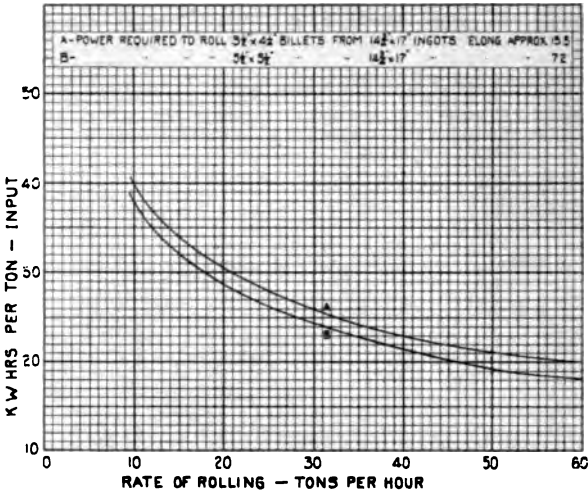


Fig. 3

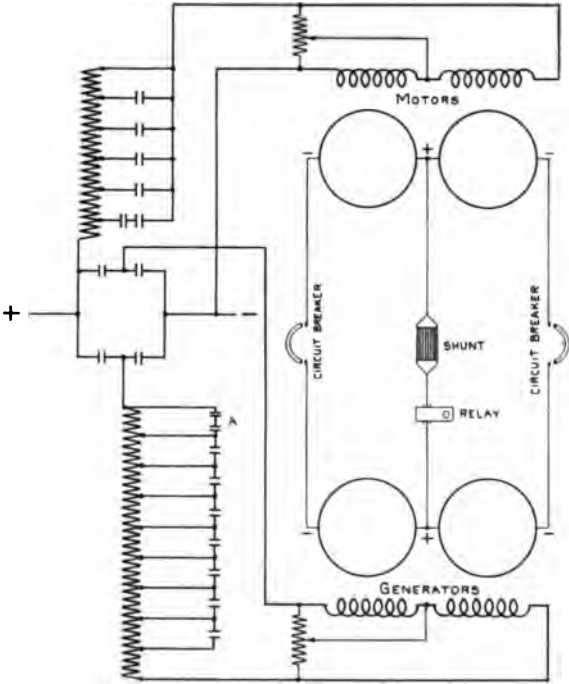


Fig. 4

conditions are maximum tonnage and minimum size that is possible to be rolled on this mill and fly-wheel set not disconnected from line.

An improvement which has been incorporated in the later installations is worthy of notice. Instead of the motors and generators being connected as shown in Fig. 4 they are connected as shown in Fig. 5. A variable potential exciter, the fields for which are excited from the current in the main leads between the motor and generator set furnish current for auxiliary shunt field coils of the motor. With

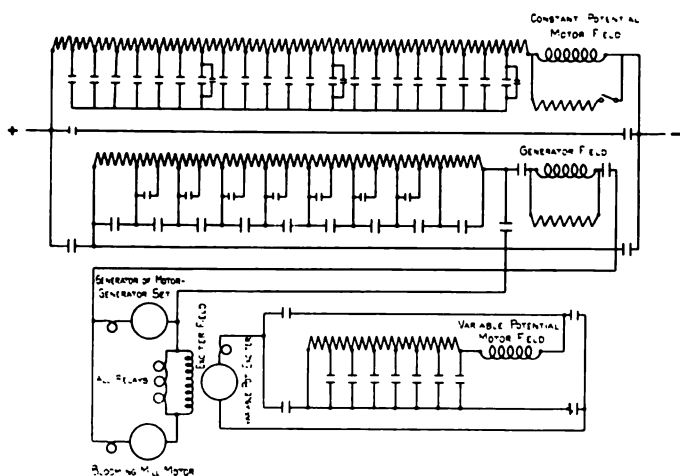


Fig. 5

this arrangement, under heavy loads a strong field is produced, giving the mill motor characteristics similar to a compound motor.

COSTS

In table 1 herewith, a comparison is given of three operating years and an average covering the same period. In 1913 the mill operated nine months and the rate per ton is high, as would be expected for the first period of operation. The 1915 figures show a very fair year considering the tonnage rolled. The individual items will represent very closely actual continuous running figures for any comparison, allowance being made for variations in tonnage. The

operating expenses, without any fixed charges, are shown here under the headings of labor, repairs, maintenance, and miscellaneous supplies, which total for the year 1915 only \$.0198.

TABLE NO. 1 (OPERATING COST PER TON)

Year	1913	1914	1915	Average or total	Per Cent
Operating	9 Mo.	8 Mo.	12 Mo.		
Tonnage	119,230	92,622	174,460	386,312	
Kw-Ton	23.9	22.8	21.5	23.4	
Power Cost	.160	.153	.144	.157	86.8
Repairs & Maintenance	.0069	.0092	.0045	.0064	3.5
Miscellaneous Supplies	.0045	.0049	.0025	.0036	2.0
Labor in Operation	.0141	.0161	.0128	.0140	7.7
Total Cost	.1855	.1832	.1638	.1810	100.0

TABLE NO. 2 (TOTAL COST OF STEEL ROLLED PER TON)

Year	1913	1914	1915	Ave.
Total operating Costs (No Overhead)	.185	.183	.164	.181
Interest on Investment (\$156,000.00)	.078	.101	.054	.073
*Depreciation (20 yrs.)	.065	.084	.045	.060
	.328	.368	.263	.314
*Miscellaneous	.126	.133	.115	.117
Total	.454	.501	.378	.431

*See Text.

The figures in Table 2 show the total cost of steel rolled per ton in our mill. The depreciation as shown herewith does not cover any question of obsolescence, but considers the equipment valueless at the end of a twenty-year period. The last item, miscellaneous, is a charge covering all electric light, power used for cranes, pumps, tables, conveyors etc. in the blooming mill, and the plant over-head charge.

The figures given under a heading of "Average" seem to be very fair figures to cover any emergency, and careful analysis by the author seems to indicate that the total figure would cover any unforeseen condition that might arise.

The largest item, power cost, is exact as it is metered, and the other items are charges made direct with no estimat-

ing, the result being that the total is an exact cost without any estimation whatever in arriving at the results. These are the actual book figures.

Unfortunately, there being so few installations in this country, no comparison between different conditions can be tabulated by the author, but as there are now building, or under way, some 12 installations, it will be possible in a few years to tabulate some very reliable figures covering the actual operating costs from such mills.

Table No. 3 herewith shows results taken by the manufacturers from another mill.

TABLE NO. 3 (ELECTRICALLY DRIVEN REVERSING MILL)

Ingot	Bloom	Elonga- tion	Kw.-hr. per ton	Remarks
18" round	7- $\frac{3}{8}$ x7- $\frac{3}{8}$	4.66	8.5	High Carbon
18x20	3x8	12.2	17.2	" "
18x20	2x16	9 2	14.5	Soft Steel
18x20	4x4	18.5	19.4	
17x15	4x4	16.0	17.9	
20x20	5x5	16.0	19.0	
20x20	8x8	6.25	12.7	

ADVANTAGES

Coming to the question of the advantages of the Ilgner System, the writer sees them as follows:

Low Cost of Power.

Low cost for repairs and maintenance.

Stand-by losses nil.

Small time to get under way from complete shut-down to rolling conditions.

Few delays necessary.

Part of rotative energy of mill parts recoverable for useful work.

Speed proportional to displacement of controller lever from off-position.

Simplicity of control.

Motor does not race when steel leaves rolls.

Constant turning moment.

Mill breakage less.

Simplifies mill layout.

Small area or ground space needed.

Lends itself to centralization of power.

Ideal load to add to any generating station.

The floor space necessary for the equipment described was 40-ftx125-ft. which allows ample room between machines and wall and switchboard, no apparatus being cramped in any way. A 40-inch mill could easily be installed in this same area. In case of necessity the fly-wheel set need not be located in close proximity to the mill motor so that in adapting a mill under extreme conditions where very little floor space was available, the fly-wheel set could easily be located some distance away where floor area could be obtained. The real estate charges on some mills located in thickly settled communities must be considered, and in comparing this area with the area necessary for boilers, coal handling machinery, steam engine, pumps, etc., the comparison is very good.

After the mill has been down for Sunday, the time necessary for the attendants to have the entire equipment ready for maximum rolling conditions is less than 10 minutes. It is doubtful whether a steam boiler equipment could be gotten under way from absolute standstill to running conditions in less than four hours. The simplicity of the control as compared to the levers, links and auxiliary cylinders necessary for the steam engine is very noticeable. The entire control wiring between pulpit and power-house is contained in a 1-inch conduit pipe. All parts of the control are entirely accessible and any part needing repairs can be changed in a very few minutes. Not considering the period of development immediately after installation, our repairs have been exceptionally low, probably the largest item being the brush renewal, but this item is very small indeed. Delays in the last three years due to this equipment, exclusive of development period, have not amounted to twenty-four hours, and this period was taken up at various times more to be doubly sure that the equipment was in good order rather than take any chance. This time was taken by such things as part of a band breaking off, loose connections, ground on the field circuit, etc.

When the mill is idle there are no losses, as the fly-wheel set can be disconnected from the line and allowed to rotate,

which means that there is absolutely no losses when the mill is idle, as compared to steam equipment having to keep the boilers under steam, the steam-line condensation, small leaks, etc. When the steel leaves the rolls there is no racing as would be the case in the steam engine run by an inexperienced operator, the motor maintaining uniform speed corresponding to the displacement of the control lever from off-position. Such complete control of the speed of the mill lends itself ideally when steel is entering and leaving the rolls, as there is no change of speed unless the operator so wishes. The motor exerts a constant turning moment in all positions, whereas the double crank engine has two weak places in each revolution and one place in particular where the turning moment is very low. The saving due to the return of the rotative energy of the mill parts to the fly-wheel gives a means of saving power which is normally lost in steam-driven mills. If 60% of the rotative energy of the mill motor is returned to the fly-wheel, 60% of this, namely 36 % of the whole is available again on mill shaft for active work.

To any plant whether purchasing power from central station or receiving power from its own power-house, the Ilgner system adds an ideal load due to the fact that it is a fairly constant load. If the mill is run to capacity the power variations will be very slight. A central station load applies in the same way and lends itself, where power is being purchased on a peak basis, to a very low rate. For a large power plant, the increased load does not amount to very much; taking as an instance of this the Hamilton mill; a 1200-kw. generator capacity would easily take care of the load. Where mills are located at various points in the plant, which from a steam power point of view is inefficient, the Ilgner system eliminates such inefficiency by centralization.

The exceptionally low cost of power is probably the most striking feature of this system, the figures shown being actual figures in no way having been adjusted for cost-keeping purposes. The simplicity of the mill layout is another feature which must be considered. The figures herewith show this advantage very clearly in regard to mill breakage. In the four years this mill has been operating, the only parts broken were the coupling boxes on the motor coupling, due each time to the metal slipping between the

rolls. During the first few months four coils were burnt out in the motor, but after this trouble was cleared up there have been no breakages in the entire mill with the exception of the coupling boxes.

TABLE NO. 4 (REVERSING EQUIPMENT INSTALLATIONS)

				Reversing Motor Rating
30"	Universal Plate Mill	Illinois Steel Co.		8,000 hp.
34"	Reversing Blooming Mill	Steel Co. of Canada		10,000 hp.
35"	" " "	Bethlehem Steel Co.		12,000 hp.
34"	" " "	Central Steel Co.		8,000 hp.
*35"	" " "	United Steel Co.		15,000 hp.
*40"	" " "	Inland Steel Co.		15,000 hp.
*32"	" " "	Inland Steel Co.		8,000 hp.
*28"	Three High Mill	Inland Steel Co.		8,000 hp.
*40"	Reversing Blooming Mill	National Tube Co.		15,000 hp.
*40"	" " "	Indiana Steel Co.		15,000 hp.
*34"	" " "	Chattanooga Steel Co.		8,000 hp.
*32"	" " "	Mark Mfg. Co.		8,000 hp.
*40"	" plate "	Mark Mfg. Co.		15,000 hp.

(*) At present being built.

DISCUSSION

W. T. Snyder: Mr. Jefferies is to be congratulated on that paper. The paper certainly gives valuable information, such as cost of rolling steel, power consumption, etc., which is very valuable indeed in our records. It is interesting to note the table of the reversing equipment installation which shows that there are four installations in operation and nine new installations building.

F. D. Egan: The author of this paper and the company he represents should be commended on the stand that they have taken, for usually information on costs, such as is found in this paper, is not given out. His data will enable any engineer to compare electric driven mills to steam driven mills with respect to operating costs and operating conditions. In my estimation, the steam driven mill will suffer from such comparison in every respect excepting first cost.

I would be interested to know the author's means of determining the shaded areas of Curve "C", also what method, type and make of tachometer was used to determine speed changes of the M-G. Set. Regarding his efficiency curve, Fig. 2, I would like to ask how data for fractional loads were obtained and to what these fractional loads apply, whether to per cent. of the full load of the M-G. Set or of the entire set and motor; also, whether excitation losses were included and whether the value of 139,043 Kw-seconds was determined by calculation from the kw. time-curve or by an integrating wattmeter.

The value of the data presented in Figs. 1, 2 and 3 would have been increased by the inclusion of information regarding the analysis of steel, size of ingot, size of finished section, elongation in per cent., temperature of ingot and of the finished billet, and the draft used. With information regarding the draft or reduction per pass together with the analysis and temperature of the steel, a proper comparison could be made between the operation of steam and electric driven mills.

While the author is right in the statement that steam boiler equipment (after being down) can not be gotten under way in less than four hours, this condition is so seldom met with in a steel plant that the comparison is not fair. However, the stand by loss is properly attributed to steam driven mills.

The author refers to photographs of steam driven mills but evidently these have been omitted. As photographs are of great value to the description of units, this omission is exceedingly unfortunate.

In conclusion I wish to congratulate the author on his very valuable paper and trust that we will have, in the future, similar papers from the various plants that are installing electric driven reversing mills. However, before further tests are made, a committee should prepare a standard method for conducting these tests so that all information will be uniform and comparable and valuable omissions will be unlikely. The mistake of conducting tests without a standard code was made by the steam engineers in testing reversing blooming mill engines, until Mr. H. C. Siebert in a paper presented before the Engineer's Society of Western

Pennsylvania, October 21, 1913, called to their attention the unreliability of information so obtained. I trust that we may profit by their experience.

Karl A. Pauly: I did not come here especially prepared to take part in the discussion of this paper, as I had previously discussed Mr. Sykes' paper at the meeting of the American Institute of Electrical Engineers. There are, however, one or two points with reference to these equipments which warrant discussion. First, it is interesting to note that considerable improvement was made in the operation of this equipment by connecting the motors in series, instead of in multiple, as originally installed. Personally, I do not understand why they were ever connected in multiple. We have always recommended the series connection of the mill motors and we never have considered the multiple connection satisfactory since the very earliest proposals which we submitted.

Further, I think considerable misunderstanding exists with reference to what we ordinarily speak of as the time of reversal. There is no question but that the mill tables, screw-downs, etc., require considerably more time than is required to reverse the mill motors, but we all know that the steel must be entered at a speed considerably below the maximum speed, and unless the mill is to be sluggish we must be able to accelerate the motors rapidly after the steel enters, and we should not allow ourselves to be deceived by believing that the electric mill will be fast, simply because we can reverse within the allotted time for performing the other operations between the passes.

The electrical problems involved, while they must be thoroughly understood and met, are not any more difficult than are met with in other fields in which motors are applied and consist, chiefly in the problem of commutating heavy overloads in current, at all voltages between practically zero and full voltage. This problem is confined almost entirely to the generator, as the mill motor operates at or near full field or under the most favorable commutating condition when the maximum demands in current occur, while the generator must commute the maximum currents at all potentials from zero to full voltage. In a properly designed generator, this problem is solved by compensating the

armature reaction by a pole face winding on the field connected in series with the armature. To get the best results this winding must fully compensate for the armature reaction. It is my understanding that some of the existing generators are only partially compensated in an attempt to cheapen them.

To my mind, the all important considerations, however, are mechanical rather than electrical, and in this respect it is my opinion that many of the equipments are rather weak. Take, for example, the shaft—the elastic limit of the steel used in the shafts runs somewhere from 30,000 to 35,000 lbs. per square inch and the breaking strength of the mill spindle is in the neighborhood of 60,000 to 70,000 lbs., or as you will note, the elastic limit of the shaft is approximately one-half the breaking strength of the spindle. As the strength of a shaft varies as the cube of its diameter it follows that the shaft must be thirty per cent. larger in diameter than the mill spindle, if we are not to strain the shaft beyond the elastic limit and therefore introduce a permanent set or injury to the shaft, when the spindle is broken by a slowly applied force. But with the shaft only thirty per cent. larger than the spindle we have no factor of safety. On the contrary since it takes time to produce motion, it is very probable that the shaft will be injured before the spindle has time to break due to the stored energy in the heavy mill motor armatures. In this respect the motor shaft of an electrically driven mill is subjected to a more severe strain and should be larger in diameter than the corresponding engine shaft. Were I the purchaser I should not be willing to accept a shaft having less than approximately 1.5 times the diameter of the breaking spindle, although this increase in the diameter of the shaft considerably increases the cost of the equipment. This increased cost is due to the necessity of using larger pedestals, bases, and more massive construction throughout as well as increased material in the shaft, all of which tend to make the equipment stronger and cannot but add to its life, especially when the pedestal must take the side thrust.

It is understood that ample precautions must be taken to provide against displacement of windings or injury of insulation due to vibrations and shocks incident to rolling

large ingots and by these mills, and where the normal draft in many cases is large and is frequently increased through inactive setting of the rolls.

D. M. Petty: I feel that Mr. Jefferies has given us a lot of valuable information on his mill, and I feel sure that in the next couple of years there will be considerably more detail information at hand with the large and growing list of reversing mill drives which are being put into operation.

So far as the speed of reversal is concerned, we have never felt that we have suffered any loss in tonnage due to the fact that our mill does not reverse as rapidly as Mr. Jefferies' mill. As a matter of fact, we have purposely kept down the accelerating time in order to limit our peaks. We had at one time a quicker reversal than we are now operating with, but increased the time, because we did not feel it was necessary, and as it was not necessary there was no use in putting the extra peak load on the motors or generators. Whether, as time goes on, we will find it advisable to change speed and increase the accelerating speed, I am not prepared to say. I feel, however, that it is well to have the accelerating speed faster; in fact, that it is always well to have a certain amount of reserve in case it becomes desirable to decrease the reversing time, but where it is not necessary, due to the fact that the ingots have to be manipulated, or the screw-down motion is very great, I do not feel that it is advisable to keep this reversing time up, because, as Mr. Pauly mentioned the fact that you cannot enter the ingot in between the rolls at high speed makes quick reversal useless. The point to be borne in mind is the fact that the motor must be able to accelerate after the piece has entered the roll.

There is one point which might be brought out in this connection, and which might be worked to advantage in the case of one or more reversing mills being located very closely together, and their products being associated and dependent on each other, and that is that it is possible to drive more than one reversing mill from a common motor generator set, there simply being a corresponding number of generating units, either one or two, as the case may be, for each mill. The saving in first cost of one motor generator set equipment and the saving in peak loads on the power station

in cutting down the weight of the fly-wheel will undoubtedly amount to a considerable item. So far as I know this scheme has not been used in this country, but I believe is in use in some European mills.

The list of advantages brought out by Mr. Jefferies I think are all well to consider, but it must be borne in mind that local conditions will determine the relative merits of all of these advantages under each particular case. So far as a comparison between steam and electric drive, directly, is concerned, I do not feel capable of going into that very much in detail, but it is a fact that in the laying out of the mill to the best advantage, from the steel handling standpoint, the electric drive will lend itself much more readily than the steam drive, because steam necessarily carries with it boilers, steam piping, etc., while the electric drive can be located regardless of the location of the power house.

The biggest factor, I think, that should be considered in the relative merits or designs of electric blooming mill drive is simplicity of operation and reliability. The size of shafts, and size of bearings both on the motor and motor-generator set should be given very careful consideration, and extra cost, for the purpose of securing extra strength and reliability, I feel are good investments, and earn all the cost put on them per ton of steel.

The speed of the motor-generator set is something I think should be carefully considered. While high speed necessarily means low cost of everything pertaining to the motor-generator set and low weight of fly-wheels, and smaller bearings, at the same time I feel that it is dangerous to consider too high speed. I recall a discussion on this subject at a meeting of the American Institute of Electrical Engineers in which it was stated in a contribution by some foreign engineer that the low speeds of the motor-generator sets in this country would not be tolerated in European practice. I think that a speed of 375 rev. per min. on the generators in driving a 35-in. mill is very near the limit.

G. E. Stoltz: I think we all agree that Mr. Jefferies has made a valuable contribution in giving us his actual costs of maintenance and operation on his mill. In making comparisons with engine drive, it has always been difficult to find out what the actual maintenance and operating costs

are. We are all agreed that electric drive operating costs and maintenance are low, but can never tell exactly how much, and here we have a contribution in which we find that the total maintenance and operation is ten per cent less than the cost of the power. These definite figures will do more good for electric drive than mere estimates. I think if the actual cost of maintenance and attendance on continuous-running motors were worked out on this same basis, the engine-builder would probably have about as much trouble in competing with electrical drive on continuous-running motors as he does have in the case of reversing blooming mill.

I think it has been mentioned at this convention that in the case of one installation a new engine was placed on a reversing blooming mill, and after a year's operation trouble was had with the foundation cracking, but orders were such they would not permit a shut down of the mill to rebuild the foundation. Therefore a reversing mill electrically-driven was purchased and placed on the opposite end of the mill, simply disconnecting the engine, starting the electric drive, and in less than two years the installation of the electric drive was paid for by the increased economies.

Mr. Jefferies brought up the question of compounding or giving the reversing motor a compound characteristic versus the straight shunt motor. The fact of giving the reversing motor a compound characteristic does not limit the speed of acceleration. In the later type of drives this is taken care of in another way, by forcing the generator field, so that the compounding does not hinder us in attaining the necessary speed of acceleration.

Mr. Petty has just explained that in the drive at his mill they have not gone the limit in the speed of acceleration or retardation, nor have they gone to the limit in the ultimate speed at which they can run their mill. They have arrived at a rate which they feel best suits their conditions, and have considerable margin if they desire to accelerate or retard their motor at a greater rate. The main reason for giving a motor compound characteristics is naturally to protect the motor. Any direct-current motor having these characteristics will be able to withstand reversing service *much better* than the shunt motor; in other words, if we

were to place on test two motors of practically the same design, except that one would be a shunt motor and the other a compound motor and simply bring them up to speed, plug them and then bring them to rest, continuing this cycle for some time, the compound motor would always accomplish this much easier than a shunt motor.

I believe one gentleman brought up the question of more detailed data in regard to the manner in which the tests were made, particularly drafts, temperatures, and an analysis of the steel. This is very important data although we find ingots are rolled at practically uniform temperature, and in most cases we can disregard the temperature. In other words the mill practice of rolling ingots is about the same in regard to temperatures. In every installation cold ingots will be rolled at times and this should always be taken into consideration when estimates are made. When ingot is hot the carbon analysis of the steel does not have a great deal to do with the power required to roll the steel. That is of more importance as the steel becomes cooler.

Much has been said in regard to the size of bearings and shafts. These matters do require attention and the selection should be judicious, considering all phases of the problem. When it is necessary to utilize from 4,000 to 5,000 h.p. in accelerating a reversing motor of this type, naturally care must be taken not to get the rotating parts bulky. Of course, we can compare the size of shafts with the spindle on the dimension basis alone, but we should not only consider it that way; we should also consider the fact that the quality of the material in the shaft, as a rule, is much better than the material in the spindle. In one equipment, rated at 12,000 h.p. maximum, we found the circuit-breaker set at 20,400 h.p. This equipment had been rolling under those conditions for some time, and I understand that the breaker had not gone out more than once or twice in several weeks; in other words, this equipment rated at 12,000 h.p., was rolling under conditions where it would develop a torque equivalent to 20,400 h.p.

This same equipment was used to roll two sizes of ingots, 19 inches square and 23 inches square. One day a 23-inch ingot was sent to the mill and the man on the screw-down did not notice the change of size from 19 to 23 inches.

It was customary to make a 2-inch reduction on the 19-inch ingot, and as this 23-inch ingot was brought to the mill it passed through the mill before he noticed it, making a 6-inch draft on the ingot. I think the size of shafts and bearings in most cases have been pretty well taken care of.

F. B. Crosby: This most excellent paper by Mr. Jefferies has been of great interest to me. I trust it may be the first of a valuable series on this important subject of reversing mill drives to be presented before your Association.

With the possible exception of auxiliary methods of obtaining an efficient adjustable-speed control of large induction motors, no other application of power for rolling steel has received such impetus in recent years as has the direct current reversing mill drive. The demand for drives of this character during the past eighteen months has been without precedent and it is scarcely a cause for wonder that in the absence of more complete data relative to first costs, maintenance, operating costs and characteristics, there has been on the one hand an unwarranted prejudice in favor of the better known reversing engine, and on the other, an inevitable tendency to select the more complex and expensive direct current reversing motor where the adjustable-speed induction motor would, all things considered, be equally satisfactory.

For mills of larger tonnage, rolling ingots of 4,000 to 5,000 lbs. and upwards, the direct-current reversing motor possesses many points of superiority, but for handling ingots of 2,000 lbs. or less, I believe there is still great reason to doubt whether the recognized advantages of the reversing direct-current motor are sufficient to offset its greater cost and complexity.

A number of these smaller reversing drives have recently come up for consideration, and in making a final selection, due weight must be given the factors of simplicity, reliability and overhead charges, as well as first costs and power charges.

The first cost of the 3-high non-reversing mill, including the necessary lifting or tilting tables, may be higher than for a 2-high reversing mill, and its maintenance may also, in general, be higher; but the interest charge against

the difference in first cost of the two types of drive will go far toward offsetting these items for the smaller mills.

The curves shown in Fig. 1 indicate clearly the possibilities of equalization of widely fluctuating demands on the main motor. Complete equalization is, of course, the ideal condition desired by the central station. It is a question, however, as to whether it is as desirable from the standpoint of power charges. If the reversing drive forms the largest part of the connected load, then closer equalization is desirable than is the case if the peaks due to the reversing mill are a smaller percentage of the aggregate of superimposed loads.

As noted in the paper presented by the Central Station Power Committee, most power contracts have a maximum integrated peak clause which determines the rate per kilowatt hour. In general, provision should be made for sufficient equalization effect to prevent the peaks greatly exceeding the average demand of the combined mill load. On the other hand, it should be remembered and advantage taken of the fact that all properly designed rolling mill motors have considerable overload capacity. Furthermore, while the flywheel is useful chiefly during the short, high peak passes which, without the aid of the wheel, would exceed in value the momentary station capacity or the economic limits set by the power contract, yet during all the remaining time—including intervals between passes and the larger low peak passes—the windage and friction losses of the fly-wheel motor generator remain practically constant. The wheel losses vary slightly with design, but may be taken as between one and two horse power per ton of wheel.

An excess of 20,000 lbs. wheel weight beyond that required by considerations mentioned above, would mean a needless annual charge with power at 1c per kilowatt-hour for 300 days of 20 hours each, approximately \$750.00.

Much importance has been attached to the equalization of steel mill loads, and up to a certain point, equalization is desirable. I am of the opinion, however, that there are in operation today, a far greater number of mills of all sorts for which the power charges could be reduced by reducing

the gross weight of the fly-wheels than by increasing this weight.

Mr. Jefferies states that "the time of acceleration of the mill motor from practically zero to full speed is only $1\frac{1}{2}$ seconds during some of the short passes." Does he mean by "practically zero" that—with the controller in the off position—there exists a tendency for the mill motor to creep, due to generator field residual which is not counteracted by the control? If so, I should like an expression of opinion from the operating engineers present as to the desirability of preventing this creeping, particularly with view to its relation to undue local cooling of the rolls, if stopped between passes, and also to the safety of men working about the rolls.

What in this instance is meant by "full speed"? In a recent paper before the American Institute of Electrical Engineers, Mr. Sykes gives the full field speed as 70 r.p.m. and the weakened field speed as 100 r.p.m. He also gives the roll diameter as 30 inches and the average length of ingot as 60 inches. The first pass would therefore be completed in less than $\frac{3}{4}$ of a revolution of the rolls. To complete the pass in 1.5 seconds would require an average speed of about 30 r.p.m. or, if rate of acceleration is uniform, a maximum speed of about 60 r.p.m. would be expected. Is this assumption correct?

I find there is much confusion in this matter of time required for reversal. The time required for changing direction of rotation is very small. With a properly designed control it should be possible to rock the motor practically as fast as the controller can be moved by hand. The time required to reach given positive and negative maximum speeds is, however, a function of the Wr^2 of the rotating parts, and the permissible maximum torque. There are certain fairly well defined limits to the rate of reversal for the higher maximum speeds since to shorten the time requires more torque; this means larger armatures and larger values of Wr^2 , so we face the old problem of lifting one's self by the bootstraps.

Many engineers have expressed surprise at the ability of the reversing motor to turn out tonnage when comparing its acceleration characteristic with that of the steam re-

versing engine. It is true that the motor is slower on the "get away", though in many cases this difference is more seeming than real. The absence of massive reciprocating parts with the attendant noise and vibration makes the operation of the motor far less spectacular, and its quiet smoothness of operation is at first apt to be both disappointing and deceptive to one accustomed only to steam reversing mills.

Mr. Jefferies mentions an improvement in the nature of the addition of a variable potential exciter, which he does not have. I am sorry that he is unable to express an opinion based on personal experience with this improvement.

This auxiliary series exciter which has been used to some extent, both abroad and in this country, while possessing good talking points, also involves certain inherent disadvantages which lead me to believe it a detriment rather than an improvement, as compared with other possibilities of control. As stated, this exciter gives the mill motor the characteristics of a compound-wound machine. It not only adds to the number of units and complexity of equipment, but if it is of any value from the standpoint of increased flux density and motor torque, it must inevitably slow down the motor under load. This means that, as the ingot enters the rolls, there is a drop in speed due to the effect of this series field which I have seen momentarily practically stall the motor until the generator field can build up to a point where the voltage is sufficient to produce an accelerating torque.

Again assuming the motor to be operating under heavy loads on the longer passes, at the instant before the metal leaves the rolls, the motor has a heavy series field from the variable potential exciter; furthermore, the shunt field has already been weakened to secure the high finishing speed, thus giving a decided series speed characteristic.

As the metal leaves the rolls, the load is off instantly. An appreciable time is required for generator and motor fields to readjust themselves to the light load conditions. The result is that momentarily the motor is operating as an underloaded series machine with a large available torque for acceleration and the motor has an inevitable tendency to race. Of course, this can be largely offset by an experienc-

ed operator cutting back the motor speed as the pass nears completion. But the tendency to sluggish operation always exists.

I have been informed that in some instances where this method of excitation is employed, the maximum speed reached is approximately 90 r.p.m. as against 120 for which the mill was initially laid out.

We have found that a properly designed shunt-wound interpole motor, with pole face windings, gives by far the best characteristics for reversing service for mine hoist and rolling mills.

The author's statement of delays "exclusive of development period" certainly is a very creditable showing. To most operating engineers, the "development period" is of paramount interest. Few mills, when purchasing equipment of this magnitude, are willing to countenance an indefinite development period, and any elaboration of difficulties to be avoided would certainly be of value.

As a matter of record of the present status of electrical reversing drives, it is unfortunate that the author did not carry his researches a little farther and include in Table IV the following equipments, either built or under construction:

- Reversing Blooming Mill, Algoma Steel Co.—7500 h.p.
- Reversing Plate Mills, Am. Sheet & Tin Plate—2000 h.p.
- Reversing Bl'm'ng Mill, Ashland Iron & Mining—2500 h.p.
- Reversing Bl'm'ng Mill, Keystone Steel & Wire—2500 h.p.
- Reversing Universal Mill, Chattanooga, Steel Co.—2500h.p.

If the 28-inch, 3-high Inland Steel Co. motor, included in Table IV, is a non-reversing equipment with fly-wheel motor-generator field control, it might not be out of place to add two more similar equipments of modest capacity:

Wheel Mill, Carnegie Steel Co.—750 h.p.

Finishing Mill, American Steel & Wire Co.—(2) 800 h.p.

I was particularly impressed by the aggregate of 145,000 h.p. represented in Table IV. The relatively small ratings I have mentioned will add little to this grand total which fact may justify their omission. I believe, however, this matter of rating reversing mill motors is one that will bear a little thoughtful consideration.

Earlier in the paper, Mr. Jefferies' motor is mentioned as 3000 h.p. continuous rating, with maximum of 9000 h.p. Table IV gives 10,000 h.p. for the same motor. This may be a typographical error, but I fail to observe in the table or elsewhere statements regarding the corresponding speeds, temperature rise or permissible duration and frequency of recurrence of these loads. Without knowledge of these factors, the h.p. ratings given in Table IV are both ambiguous and misleading and afford absolutely no adequate basis of comparison between existing or proposed installations.

Few subjects relating to motor design and application have demanded, or received, more careful consideration than that of rating. Its aspects are so varied as to render a clear yet concise exposition very difficult. To do so, it is necessary to keep clearly in mind a few basic definitions of terms commonly used and misused.

First; torque or turning effort is usually expressed as force (pounds or other units of weight or pressure) acting at unit radius. For example, "100 lbs. torque" will be assumed as the equivalent of the turning effort or torsion produced by a pressure of 100 lbs. acting tangentially at a distance of one foot from the axis about which it tends to produce rotation.

Torque may exist either with or without motion. In the latter case, it is sometimes spoken of as static or starting torque, and in the former as running torque.

Second; work is the effect of force acting through distance. Static torque represents force but not work, whereas running torque or force in motion always performs work which may or may not be useful, depending upon the efficiency of the medium of transmission.

Third; horsepower is a measure of the rate of doing work and, in addition to the two factors—force and distance, introduce a third consideration, time. Much confusion often arises through lack of a clear understanding of the relation of these three factors. The unit horsepower is still taken as arbitrarily designated by Thomas Watt, namely, the ability to do work at the rate of 33,000 foot-pounds per minute or its equivalent in corresponding units.

The term horsepower, taken by itself, may be very misleading with respect to the ability of a motor to trans-

form electrical into mechanical energy, unless specifically or by unmistakable implication the factors of torque, speed and time are known.

Fourth; the terms h.p-hr., h.p-seconds, etc., are also most useful as a measure of work, particularly where the work is of an intermittent character with either a regular or irregular recurring duty cycle. Wherever rotating or reciprocating masses are subjected to frequent and rapid acceleration and retardation, it is most convenient to deal with the transfer of energy in terms of torque-seconds or h.p-seconds.

Each of the four terms and definitions discussed above, namely: torque, work, horsepower and h.p-seconds, are applicable equally to all forms of mechanical devices for transforming energy into useful work, whether that energy be in the form of heat in air or steam, the stored energy of air or water in motion, or electrical.

Confining these remarks to motors for transforming electrical to mechanical energy, it is evident that with a range extending from a simple application of torque without movement, through applications in which practically the entire energy input is utilized internally to accelerate a given mass, and those requiring high accelerating torque together with short intervals of useful external work, on to applications requiring a continuous energy transformation at constant output, it is difficult indeed to name the capacity of the motor or—in other words—assign a rating.

Large motors for main roll drives are practically always designed either as direct-current machines with special field windings or, in by far the great majority of cases, as alternating-current machines of the induction type. In either case, the following points must be given consideration in arriving at a rating:

- (1)—Speed revolutions per minute.
- (2)—Torque.
 - a—Starting
 - b—Continuous running.
 - c—Maximum momentary or pull out.
- (3)—Duty
 - a—Constant or intermittent output.

b—If intermittent—

a—Frequency of peaks.

b—Duration of peaks.

c—Period of rest or friction.

(4)—Reversal

a— WR^2 of rotating parts.

b—Rate of acceleration.

c—Frequency of reversal.

(5)—Relative importance of

a—Starting torque.

b—Maximum torque.

c—Efficiency.

d—Power factor (if a-c).

e—Speed regulation.

f—Commutation (if d-c).

(6)—Heating

Unlike the steam engine which is limited in momentary output by cylinder dimensions and boiler pressure, the electric motor is limited by permissible temperature rise and, in case of induction motors, maximum torque; or in case of direct-current motor, commutation. Temperature, torque and commutation are the limiting features, and for purposes of this discussion, these may be reduced to temperature and commutation.

Although the most striking characteristic of the average steel mill roll-train resistance diagram in its extreme irregularity of profile, it has been customary to rate constant and adjustable speed non-reversing motors on the basis of temperature rise when delivering a specific shaft horsepower for a specified period.

Nearly all main roll motors have been sold under one of the three following guarantees based on room temperature of 25° C.

A—Industrial or "A" heating.

Normal load continuously temp. rise 40° C.

125% load 2 hours temp. rise 55° C.

B—Steel Mill Heating

Normal load continuously temp. rise 35° C.

125% load continuously temp. rise 50° C.

150% load 1 hour temp. rise 60° C.

C—Special Heating

125% load continuously without injury.

Some electrical manufacturers have combined (A) and (B) giving temperature rises of 40, 50 and 60°. Tests show, however, that a motor designed for a 50° rise at 125% continuous load will not exceed 35° under normal load. It is extremely difficult to check loads under operating conditions, and it is obvious that if there is a tendency to "take chances" on the overload conditions, the 40-50-60 basis permits the use of a less expensive machine, although—to casual observers—the two machines may appear to meet the same specifications.

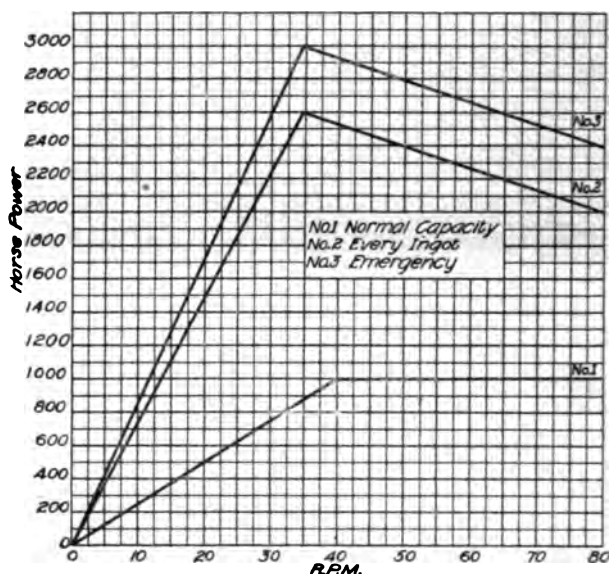


Fig. 6

Nowhere is the lack, among different manufacturers, of definite basis of rating motors more certain to result in a misunderstanding of motor capacity than in connection with reversing mill motors. For example, the reversing blooming mill motor at Bethlehem is given in Table IV as 12,000 h.p., but no mention is made of any of the several important factors necessary to a real definition of its capacity. Neither speed, torque, temperature rise, or duration of load is mentioned. It is evidently a maximum rating,

and therefore at variance with established practices as regards the rating of all other mill motors.

The motor we quoted in competition was rated 3600 h.p. continuously at 35° C. rise with 125% load continuously at 50° C. rise or 150% load for 1 hour 60° C. rise without forced ventilation. It was good for approximately 14,500 h.p. maximum output at about 60 r.p.m.

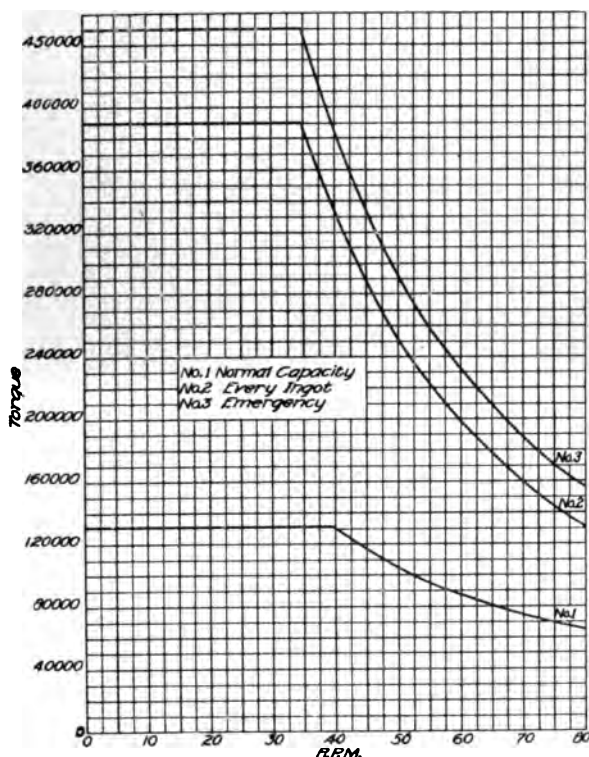


Fig. 7

The Central Steel Company's motor bears a nameplate stamped: "670,000 Pounds Maximum Torque at 47 r.p.m.", corresponding to but 6,000 h.p. maximum, whereas the motor is listed at 8,000 h.p.

Practically the same conditions exist in connection with the Steel Company of Canada. We quoted on a normal rating of 2,000 h.p. In Table IV the motor is listed as 10,-

000 h.p. The reason for this discrepancy may lie partly in the fact that during the development period mentioned, artificial ventilation was provided for both the generator and the motor. This takes care of the temperature and leaves commutation as the limiting factor in capacity rating.

In order to place the reversing mill motor on a definite rating basis, the General Electric Company includes in its specifications two sets of curves (as shown in Figs 6 and 7) together with a statement of guaranteed temperature rise when carrying normal and stated overloads for stated periods. Fig. 6 shows these curves plotted in terms of h.p. against speed.

No 1 corresponds to the normal rating or continuous load which the motor will carry with stated temperature rise.

No 2 indicates the h.p. which the motor will develop when operating on a guaranteed rolling cycle of stated frequency of repetition.

No. 3 indicates the h.p. which the motor will develop in emergency without injurious sparking.

In Fig. 7 are shown corresponding curves plotted in terms of torque and speed so that these two sets of curves, together with a statement of guaranteed temperature rise and a definite duty cycle, comprehensively define the capacity of the equipment.

I do not know the normal continuous ratings of the motors in Table IV, nor the temperature rise upon which the 3,000 h.p. rating mentioned by Mr. Jefferies is based; but assuming that each motor listed will carry a continuous load in the same ratio of 3,000 to 10,000, the grand total h.p. ratings shrinks to less than 50,000 h.p.

The reversing mill motor ratings which I have added are continuous ratings.

I can see no more reason for rating reversing motors on the basis of maximum momentary output than for following the same practice with respect to induction motors. For example, the 6500 h.p. General Electric motor in the 60-inch Universal Plate Mill at Gary will carry:

6500 h.p. continuously with 35° C. rise.

8125 h.p. continuously with 50° C rise.

9750 h.p. for 1 hour with 60° C. rise.
and it has a maximum output of practically 24,000 h.p., yet we always advertise it at its normal output of 6500 h.p. Have we been too modest?

H. J. Sage: Unfortunately, I did not hear the beginning of the discussion, and I do not know what has been said. The paper spoke of large reversing sets. You may be interested in hearing of a small installation that has worked out very satisfactorily. This installation, which is in operation in the Chicago district, consists of two direct-connected motors driving bar mills at 20 revolutions, the motors being operated from one motor-generator set. The reversing curves, which were calculated before the motors were built, were based on a complete reversal from .7 full speed to .7 reverse speed, in one second, using a dynamic braking current of 100% momentary overload. In actual service at the time the mill was installed, using a dynamic braking current of 150% full load, the reversing of the mill was obtained in .86 of a second. Of that time .3 of a second was consumed in the manipulation of the contactors of the reversing controller.

These reversing motors are working very satisfactorily and have not caused a moment's delay on the mills.

This is a case where two reversing motors are operated from one motor-generator set. It is a comparatively small motor, 800 h.p., and the control is a well known armature control type. The field is constant, and is not reversed; and for this reason we do not have to take into consideration the building-up or demagnetizing effect of the field.

G. E. Stoltz: There was one question brought up in regard to stalling some of these equipments. I think the man who made the statement did not realize that very often these motors are slowed down due to the rolls slipping on the mill. This ease of control is one of the greatest advantages the electric drive has over the engine drive; in other words, if the rolls begin to slip the equipment can be brought down to a slow speed and sometimes it must be brought to a standstill before the rolls grip the metal and the motor can be accelerated and the pass finished. The creeping of the rolls was taken care of in some of the installations, but it was found undesirable. It is more desir-

able to have the rolls turn very slowly, so that the water will be distributed over the whole roll instead of only to one side.

In regard to the rating of these equipments, there are different fields of application, varying from continuous service to intermittent. We have the continuous rated motor for blowers, etc. We also have the one-hour mill rated motor and the one-half hour crane rated motor. Here we have an application requiring an instantaneous rating. In other words, if you will note the curves which Mr. Jefferies has given us, you will see that the limitation or the feature which determines the design of this equipment is the load that the equipment must stand at the beginning of each pass. During the first few passes the peak lasts through the whole pass, but it is only for the duration of a few seconds. During the finishing passes the peaks are acting during the first part of the pass, when we not only require the torque to roll the metal, but also friction and acceleration, so that the design of these equipments is determined more by the short peak load which corresponds to the rating that has been given on most of these equipments than on the heavy load.

The Bethlehem equipment was installed with artificial ventilation. That is required more due to the churning action of the air on account of frequent reversals of the motor and slow speed of rotation. In case of the Steel Company of Canada, in the first few passes the motor did not obtain much over 25 rev. per min., and in reversing back and forth at such slow speed it is practically impossible to ventilate the machine, except by means of artificial ventilation. In Bethlehem the intake was near some gas producers and considerable gas and dust was brought in through the machine. It was therefore necessary to dispense with artificial ventilation. The enclosing cover between the two units was removed and the air was allowed to go out into the room in order to ventilate the substation.

The Bethlehem Steel Company's equipment is still operating without the aid of artificial ventilation. This is a new mill and although they are not up to the tonnage they hope to attain, it illustrates the folly of trying to rate these equipments on continuous capacity. The main thing one is in-

terested in is to obtain an equipment which will successfully roll the steel, and whether the customer gets a 2500 or a 3500 h.p. continuous rated motor will mean very little to the purchaser.

R. W. Davis: The list of reversing equipments at the end of Mr. Jefferies' paper is interesting in that it points out the large increase in the number of electrically driven reversing mills that has been made in the last few months. We notice, however, that one of the earliest electrically driven reversing blooming installations made in this country has been omitted in the list. The Algoma Steel Company has had an electrically driven blooming mill in successful operation for several years. This mill was started in 1911 and was laid out for rolling 20" x 20" ingots to blooms. The mill is driven by a two unit motor rated 4000 h.p. normal (continuous) or 10000 h.p. max. (Reversing motor rating) at 75 r.p.m. Power for this motor is supplied by a fly-wheel motor generator set, consisting of an 1800 h.p. induction motor, a fly-wheel, and two 1700 kw. direct current generators operating at 375 r.p.m. synchronous. Both motors and generators are of the shunt interpole type with compensated fields.

David Hall: As considerable has been said in discussion of this paper, regarding the relative merits of a straight shunt field motor versus a motor having a field so excited as to give an increased field strength with an increased load, I feel that some further explanation in regard to this point should be made.

The compounding effect which has been referred to is obtained by supplying the mill motor with two field windings; one of these windings is excited from a constant voltage; the other winding is excited from a machine, the voltage of which increases with the load. Such an arrangement gives to the motor a kind of a cushion effect, and it also affords a means of controlling the amount of peak load. If, for any reason, it is preferred to operate a motor as a straight shunt machine, instead of making use of the compound characteristics, it is only necessary to change the connections and excite both of the motor fields from a constant potential. Emphasis is called to this particular point because some many have thought that when a motor is built

for operating with the compound characteristics that it could not be operated as a straight shunt motor.

One of the speakers referred to some attempt having been made to cheapen this class of equipment by partial compensation. Having had charge of the design of all of the motors referred to, and tabulated on last page of this paper, with one exception, I can state positively that all of these equipments have been supplied with full compensating windings, and any reference to partial compensation must either refer to other equipments or contemplated equipments. Any gain in cost which might be made by using partial compensation, that is, by having less ampere conductors in the pole face than on the part of the armature which is covered by the pole face, would be extremely small, so long as the machine is made of the compensated type,—entirely too small in the writer's opinion, to be seriously considered. In fact, in the design of all these equipments, good performance and rugged construction have been the determining elements in the design.

E. S. Jeffries: Mr. Egan asked how we determined the shaded areas of Fig. 1. The areas were determined where the oscillograph records of the current crosses the zero line. The bottom curve, curve D in Fig. 2 is obtained from oscillograph records of current and voltage.

As to the efficiency curve, in Fig. 2, the fractional load points were determined by allowing for the frictional losses of rotation, i.e. considering the area at the 50 per cent. point: 50 per cent. of the time was being consumed for frictional losses and for 50 per cent. at the rate as shown in Curve D.

As to the question of the input as shown by curve "A" being 139,043 kilowatt-seconds, that was determined from the curve as plotted from the oscillograph records.

As to the questions regarding the record of the figures in Tables 1, 2 and 3, of the analysis of steel roll, size of ingot, finished section, elongation, percentage of temperature of the ingot, finished billet, etc., these figures you will appreciate, were taken over an average of three years, the analysis of the steel varying quite widely and the size of the ingot remaining about 15" x 17" and the size of the finished section averaging from 31½" x 37½" up to 8" square. The

draft on the first few pieces was practically always 2" or 2½", although to see what the equipment would do we have rolled up to as high as 3½" and 4" reduction, but the quality and analysis of steel for ordinary rolling does not allow us to take these heavy drafts.

Mr. Crosby spoke about the equalization of the load due to the fly-wheel, and the curve shown here was taken when we were rolling only about fifty per cent. capacity of the mill and since then we are rolling steel now which has loaded the mill practically up to its capacity, and we find there that the input of the motor-generator set is practically a straight line, there were slight variations between ingots and passes, but that is now practically constant, due that the set is practically worked up to its limit.

As to the question of the creeping of the mill when not rolling, the motor does creep very slowly, probably not more than one rev. per min., due to the residual magnetism in the generator fields, but if the mill is to be down any length of time opening of the field circuit-breaker prevents this and prevents any accident due to men repairing or working around the mill.

I believe in one installation that is being equipped now special means have been provided for rotating the mill motors slowly in order to replace broken couplings of spindles. It seems to me that the extra expense in providing a separate motor to do this is really unnecessary when the motor can be rotated as slowly as even half a revolution per minute with the normal equipment. We have not found any difficulty in rotating the motor slowly enough to replace any spindles or boxes.

The speeds referred to of the motor as contracted for were 70 rev. per min. full torque and 100 rev. per min. at reduced torque. That is the approximate conditions under which the test data was taken, as shown in the paper, but since then, due primarily to a reconnecting of the set, parallel to a series connection, these speeds have been increased to 72. rev. per min. at maximum torque, and 125 rev. per min. at reduced torque.

In stating that the variable potential exciter seemed to retard acceleration, I did not mean that to apply same to reversal, but *only* to acceleration. The characteristics of

the compound motor do retard the motor in accelerating under those conditions, but since watching the Bethlehem mill I am sure that the time of acceleration, which is important when the mill is loaded to its capacity, is retarded slightly, and whether it will affect the tonnage in the end or not, I am sure only experience will tell.

The Table given at the end of the paper regarding installations is very incomplete, but I am sorry to say that the manufacturers refused to give any more information, and I put that in, primarily to show the number of installations being installed at this time. The ratings given were the ratings given me by the manufacturers, and is all I could go by. All ratings should be stated in a table like this, as h.p. per r.p.m.

THE VALUE OF RECORDS TO AN OPERATING ENGINEER

By RAY S. HUEY

When an engineer, after numerous promotions, reaches the degree of success where he becomes the head of the department, he soon is confronted with the problem of costs. There is not a move made nor an article used that does not cost money, and the engineer's value to his superiors is measured by the cost of operating the department under his regime compared to that of his predecessor. Without any previous experience he is unable to put his finger on the high spots and he gropes around in the dark until he gives the matter enough serious thought to formulate some plan to get his costs into some shape that are intelligible to him. If he is of an investigating turn of mind and wishes to know why some things seem to cost more than is necessary, he will soon start some comparative records, probably crude and simple at first. These will be amplified as time and experience require.

Although the final manufactured product may be the same, local conditions make the methods of procedure more or less different, so the engineer must, by necessity, work out his own salvation and adopt methods of his own to suit his own particular needs. It is therefore impossible to make a standard that we can say is suitable for all conditions. Any record that is of any value whatever should be accurate, and to be accurate it should be automatic. By that I mean that it should be kept up at all times as part of the every day routine and should not be a record of an isolated case or one that has to be dug out of a maze of figures, or data of doubtful value, which, when finished, cannot possibly be as accurate as one that is kept up as part of the regular work.

Unless this is done as routine work, one of the human cogs in machines forgets to do his part at some critical time, and the results of a test or trial always depend on more than one person, and the record is then incomplete and inaccurate and therefore may be misleading.

When the relative merits of a purchased article are considered, if a record or series of records, on a number of competing articles, are available, it carries infinitely more weight in an argument with the salesman and the purchasing department than an occasional record, because it is clearly to be seen that the chance for error is a great deal less when the record is kept automatically and completely for any and all, regardless of whether it is a special test or not.

Special tests, by the way, are, as a rule, quite unreliable and it is generally only after repeated tests that the advantages and disadvantages are fully known.

It is with these thoughts in mind that this paper is presented, to give you a few ideas that have been impressed on me, in the hope that it will be of some assistance to those that desire to obtain more definite information regarding the details of their departments.

When a company expands and builds new plants, the organization is new and more or less inexperienced and there is no one who knows the cost of this or that detail. At the end of the month, a statement is received from the accounting department, giving the cost of each item on the cost sheet.

Any detailed costs are obtained only by great effort and are unreliable. I do not mean to cast any reflections on accounting departments, but the ordinary facts and figures from which these details are obtained are not sufficient from which to get accurate results.

As time goes on and experience increases, a system is devised that gives invaluable and reliable records, and costs no more than the old unreliable methods.

In the office may be a clerk, whose duties require him to keep a set of record books that should be up-to-date at all times.

These books are of the loose-leaf variety, composed of sheets on which is ruled and printed in a quantity, or ruled by hand the substance of the record to be kept. Each ma-

chine and part, on which a record is kept, should have a separate sheet, and if the number of sheets is large enough, due to the number of machines or to the number of parts replaced, to warrant the expense of a printed sheet, it is a labor-saver, but for those starting a record it is advisable to rule up the sheets by hand the first time, on account of the frequent changes necessary to get the record into a more or less complete and satisfactory state.

Each sheet should be ruled up to suit the needs of the particular machine of which it is to be the record, and all the parts should be included in it, so that the sheet is a complete record of that particular machine.

In our particular case, each foreman in charge of a number of men in the mechanical, electrical or operating department makes out a mill report, some on printed daily report-sheets which are sent to the office for cost and output purposes, such as the operating department, and some on a plain sheet of paper where a printed form will not do, such as the mechanical, and electrical departments. The operating department in the "remarks column" makes note of any machine down for repairs and states in general what is being done. On the mechanical or electrical foreman's report, a detailed statement is made showing the pattern number of the parts changed, or any other identifying remarks if it has no pattern number, and the reason for the change, such as broken, worn out, etc.

When the article is purchased from the storeroom, if it has anything special it is tagged with those features explained and this is embodied in the report.

On any very particular or expensive replacement, it is customary to have a copy of the store ticket forwarded to the superintendent's office. These items are very few but it is another check on the time it was put in. This is also done to call this matter particularly to the Superintendent's attention, as he may wish to make some personal observations of the article in use.

After the superintendent has made his usual daily inspection of the reports, they are forwarded to the clerk who enters in his books, each item, against its respective mill, giving date installed, the reason for its installation, material and any other illuminating remarks in the report.

When a new part is entered as having been installed, it is obvious that the old part is removed and either that it has served the limit of its usefulness or has to be rejuvenated and put back; all of which can be taken care of in the record. If there are a number of the same articles in one machine, the parts are numbered and the record kept of the numbers and it then makes no difference if the parts are taken out and put in another machine of the same kind, as the record follows the number.

If it is removed on account of its inability to be of further service, the clerk from the mill practice records gets the actual life in hours, days, weeks or months or it can be worked out to give results in tons made, or barrels conveyed, or any other desirable unit.

If it is desirable to go further, a column can be provided for the unit cost of operation which will work out as cost per hour, day, barrel, ton, etc., which is the figure desired. This can be misleading if the proper unit is not selected, as an illustration will show: A belt conveyor was installed and a number of belts used. The record had been kept to show the cost per hour of operation. It was observed that the more recent belts were not showing as good cost per hour and, after going over the record carefully and comparing the quantity of material conveyed which after all was what was desired, it was found that on account of the increased capacity of the plant at the later date, the later belts had conveyed much more material than the first ones and therefore the cost per barrel was less while the cost per hour was more.

Since the cost per barrel was the unit, it is needless to say the accounting department employed that the costs of all belts after that were recorded in cost per barrel.

After the record had been kept for some time and a study made in some particular, there will be facts standing out so boldly that the wonder is they were not seen before. A different quality, a different kind of material or any other variation out of the ordinary is instantly comparable with years of past experience and it has been the means of reducing the cost of some repairs, not only 10, 20 or 30%, but in some cases 500%. These, however, are rare cases.

Most records not kept in a regular way are kept in someone's memory, and after a set of records has been kept it is very interesting to see how exceedingly unreliable, untrustworthy and misleading the memory can be.

Furthermore, when the record is left to the memory of someone or ones, a salesman may have good reason to believe that his goods are not getting fair and impartial treatment and, in some cases, it may lead to even more sinister thoughts, but when confronted by actual records, he should have no doubt in his mind that he is being fairly and generously treated. On account of the records, the salesman goes back with a report from which his firm can work to improve the quality of output of the article in question—quite frequently with success. The improved article then helps the operating engineer to get better results which, in turn, decrease costs.

I also believe that you get more courtesy and respect from salesmen or engineers, as they will not take up a busy man's time in trying to sell an article if they can see for themselves that the article is unsatisfactory. On the other hand, if evidence is not at hand, the salesman may confidently believe that the article will be suitable and economical, and he may be right if you cannot argue with any facts to back you up.

A few instances will show how valuable these records may become. A certain mill required 20 heavy, expensive, steel plates which, although made from the same heat, seemed to give very widely different results. It was only by means of the records in connection with experiments relating to the mixture, analysis and heat treatment that the service of these plates was increased. Some of these plates lasted a year or more and while they were 3-in. thick at the start, wore to a thickness of less than $\frac{1}{8}$ -in. before they broke. Others would break and split from end to end in one day and it was necessary to dismantle a machine and install a new plate, which was a long and expensive delay. Analyses were made and the good and bad plates might have the same analyses and no results were obtained from them. A microscope was purchased and the steel of a good plate was examined physically along with the chemical analysis. Then the bad ones were examined the same way and photo-

graphs were made. Different heat treatments were then tried, as the physical analyses seemed to show that the steel had not been properly heat-treated.

By comparing the records with the data obtained from these analyses, both physical and chemical, it was noted that progress was being made in the plant. By the continuation of this investigation, the plates were finally manufactured so that they all gave uniformly good results.

The extra service obtained from these plates alone would pay for the cost of keeping the records in the whole plant.

Another illustration, showing the advantage of a record in a minor detail, is one on incandescent lamps. It showed at first that the life of the lamps was very low. Upon investigation, it was found that the voltage of the system fluctuated greatly, so a Tirrill regulator was installed. The record was then kept of all lamps, 250 watt and above. When a lamp was installed, the date was scratched in the skirt of the base and when it came out, this date was also scratched on it. A tag was then attached to the lamp giving location used, date in and out, life in hours and the reason for its failure if known, such as broken filament, poor vacuum, glass spalled off at leading-in wire, etc., with any remarks when something out of the ordinary occurred. This lamp was taken by the foreman to his office where he has a book in which he or a clerk enters this information. The lamp with its tag then returns to the storeroom where it is kept safely until inspected, if desired, by the manufacturers representative if the life has not been up to its guarantee. When the manufacturer's representative, who adjusts these matters, comes to the mill, is shown the records together with the lamps and actual results on which to base his reports, and a settlement of a claim is always satisfactorily adjusted with the feeling on both sides that there is no guesswork about it.

Another valuable minor record was one kept on fuses. In this mill were approximately 600 a-c., 25-cycle motors. These motors were fairly well loaded, but due to variations in voltage and frequency a very large number of fuses were blown daily. It would have been impossible to have kept in stock enough fuses to last until new ones were purchased

and it was necessary to refill the old ones, which was done as needed. The fuses were finally turned over to the store-room, which placed orders on the shop for refilling and a record of the cost of refilling was made.

All labor and material were charged up and a comparison made of the cost of refilled fuses against new fuses, and also against the refillable fuses.

Records on motors, showing the location where used and causes of failure, will go a long way toward correcting the trouble when the causes are apparent.

During the recent depression, a reduction in the number of men in the shop was imperative so the shop crew was divided into two groups. One group worked two weeks and then the other group worked two weeks.

By the aid of the shop records, it soon became apparent that certain men were able to accomplish twice as much as the men that worked on the same work the previous week. It was therefore possible to get more out of the slower ones by the competition and to weed out the drones.

Another record of great value is the pattern record. In the ordinary mill, repairs are made at the plant on practically all the mechanical and electrical machinery. The patterns of the parts are made and castings kept in stock either rough or machined. It is one of the most difficult tasks in the plant to get the right casting every time it is needed, and it is frequently the case that the record of the casting cannot be located at all by the man needing it, or the storekeeper. It may be in stock but the man asking for it may not know the name or pattern number and the storekeeper, not being a mind-reader, is unable to satisfy his customer. Pattern records were kept in consecutive order but in this shape they were useless. A number of records were tried with indifferent success but it finally led to a pattern record that seemed to fill the bill for both the mill and storekeeper. A tracing was made on a sheet about 8-in.x10-in. and a sheet made for each mill, machine or motor. On this sheet were recorded every part used on the machine. If the part had a pattern number, it was given with the name or description of the part, material from which it was made, drawing number on which it was shown, the building, the machine it was in, number used per unit and any other remarks. If it was

a forging or a coil or some other part, it was listed also under the machine of which it was a part, so when the sheet was complete it was a complete record of the parts of the machine.

These sheets were blue printed and bound into a booklet with brass split pins with a tough paper cover. These booklets were then distributed among the foremen and to the storekeeper. When the men came to the foreman for a repair, all the foreman needed to do was to refer to his reference book and knowing what machine it belonged to, it was easy to identify the particular part and send an intelligent order to the storekeeper. It took less time to find out what was wanted and less time for the storekeeper to fill the order and has been very satisfactory.

In conclusion, I want to say a word of warning, as there is a danger of carrying this matter of records too far. When their value is realized and a system is started the engineer may feel that he wants records of everything and then to go to excess in the matter, so that the expense of keeping them up is not justified by the advantages derived.

Therefore, one of the important questions to be decided is what records are of enough value so that the information derived therefrom will warrant the necessary expense of keeping them and, that having been decided, the next thing is just how to keep the records to give the desired information. This last question will eventually take care of itself, as only by a trial and subsequent alteration will a record be found to be complete enough for satisfactory use.

DISCUSSION

F. A. Wiley: We agree with Mr. Huey in every point that he has brought out in his paper, relative to importance of keeping accurate records of all repairs and replacements. If you want to know just what it costs to make a certain article or the cost to operate a certain department, an adequate system of costs is necessary. It is not absolutely necessary to have a complete shop order or cost system to know what the finished product will cost, the accounting department

can tell that at the end of the month or at the close of the year. Suppose that when the accounting department submits the cost for the previous month to the management, and the cost of the finished product would be higher than he had figured on, and they should ask the department superintendent why it cost so much to run his department last month. He would be unable to say unless he had an accurate account of all work done in his department for the month or year as the case may be. These records can only be kept by a correct shop order system.

It is true that it will require extra help to keep up a shop order and record system, but I believe that it is a money saving proposition in the end. A complete record of the cost of all repairs of the individual machines is the most convincing argument that a man can produce when he has occasion to go to the general superintendent and ask for certain improvements to be made in a certain machine. All work passing through the repair department should be handled by a suitable shop order system, no matter how large or how small the job may appear. There are times when apparently a small job will develop into a very large cost before it is completed. I also believe that the shop cost-system has a tendency to lower the cost of a great many jobs of work that pass through the repair shop, if a workman knows that he can be readily checked up on the number of hours that he put in on a certain piece of work and the amount of material used is a matter of record, he will in my opinion be a little more careful, than if there was no record kept of the job. The value of adequate records cannot be too strongly emphasized. I also believe that a suitable system of costs has a tendency to increase the efficiency of any department in any class of manufacture.

Ludwig Hommel: Mr. Huey's remarks have dealt mostly with records pertaining to maintenance and up-keep costs. I should like to have you consider the records by which you obtain your power costs, also the distribution of such costs among the various departments of your plant, and the importance of these records.

The first requisite toward obtaining cost per kw-hr. is to know the total kw-hrs. generated in a given time. This is invariably done nowadays by means of watthour meters.

Dividing the total kw-hrs. into each of the component parts that go to make up the total cost of generating the electric energy, such as cost of coal, boiler room expense, engine room expense, machinery up-keep, coal and ash handling, etc., the cost per kw-hr. of each of these component parts is obtained. Comparing these costs per kw-hr. with similar records in the past or with similar records of other plants, excessive cost items are quickly located, and remedies can be applied. A good many companies have adopted a standard system of accounting and reporting for purpose of obtaining the records just mentioned.

Of equally great, or even greater, importance than determining the cost per kw-hr. is the accurate distribution of the total energy cost to the various departments of the plant. In the first place, it is a fundamental necessity for any manufacturer to know that his products cost him and what each manufacturing operation costs. Without that exact knowledge he cannot be certain that his sales price is giving him proper margin of profit. Without this information he also has no comparison from month to month whether his manufacturing costs remain constant or change. Without the cost of electric current being included, the cost figures of manufacturing operations are incomplete.

Considerable savings in the use of electric energy are almost always effected whenever a system for accurately distributing cost of electric power is installed in a plant. Let me cite a few examples which will illustrate the reasons why such savings are effected. In one instance it was found that the lighting when metered separately from the power, actually used more electric energy than the machinery in the department. A rearrangement of the lighting layout resulted in a considerable saving. This was due purely to knowing the actual figures.

In many other instances when the foremen found that account was being kept of the energy used in their departments, they became careful to see that lights were turned off when not needed and machinery shut down when not required. Incidentally, this removed an excuse used by some foremen when confronted with high operating costs, namely that such high costs were due to an unfair charge against *their* department for energy used. It is found by experi-

ence that the saving due to exact knowledge of energy cost is permanent, because the foremen and operators in the departments realize very soon that an exact record of the performance is taken.

When comparing actual, accurate figures with previously assumed figures for departmental energy costs, very great discrepancies are often found, and consequently low production costs may be found to be high, and vice-versa.

An important use of records obtained by means of watthour meters or graphic recording meters is found in comparing the cost of energy of different departments which have similar equipments in use or comparing the energy costs of different equipments in the same departments and under the same operating conditions.

Many mills have storage battery installations for regulating and stand-by purposes. To obtain a check on the efficiency of these batteries, ampere hour meters are very valuable. They are also highly important in preventing unnecessary overcharges with resulting shortening of life of the battery, etc.

As an example of what results can be obtained by intelligent use of watthour records, let me refer to the so called "Economy" Street Railway Meter and record system worked out for same. While this does not apply directly to steel mills, yet I believe a few words on it will be of interest as possibly offering some suggestions to the mill engineer.

"Economy" watthour meters are installed on street railway cars, being read at the end of each motorman's run, or upon changing crews. These records computed against mileage show the kw-hrs. per car mile for each motorman. Knowing that a record is kept of his efficiency in operating his car, the motorman soon learns to handle the car in the most efficient manner, and this is at the same time the manner of operation which will cause the least wear on the car, besides saving energy that runs up to a great deal of money in a year's time. This also has the effect of making the motorman more particular to see that his car is in good condition when he takes it out, which, in turn, makes the shop look over the equipment much more carefully.

The street railway companies also have obtained excellent results by comparing energy consumption of various types of equipment over the same route to see which is best suited, etc.

In conclusion, it has been my experience among a large number of mills that records obtained by the metering of energy generated or bought and of its distribution among departments are productive of quick and lasting material benefits. They are very easily and accurately obtained and at a low cost.

C. S. Lankton: I have not been able to prepare a discussion of this paper. All that Mr. Huey says I fully agree with. Oftentimes it is quite hard to obtain the co-operation of the people in your department. They do not see the necessity of systematic operation in reference to records. They do not see the value of it. They think that you are carrying things to an extreme which is not called for. Hence, when you try to systematize it should be started out gradually. The important thing should be started first, and by showing the people in your department the value of systematic records, then you can increase your activity into some other department, and in this way work from one thing to another until finally you get your plant wholly systematized.

A. G. Pierce: Mr. Huey's paper is most valuable. The cost division of a department is its heart. Mr. Huey has truly stated that no department makes for continued success without a well organized division for co-ordinating its technical and financial data; performing this work systematically and regularly, studying to obtain sufficient data for conjectured requirements and yet limiting its volume to what is really wanted. There is a passing tendency to overlook the cost division, to consider it an overhead expense, to magnify the intelligent guess. I have called this a passing tendency because, with Mr. Huey, I believe that department heads more and more realize the importance of reasonable exactness, and must rely on the regularly obtained results of the cost division as a basis for their conclusions. Specific comment on three points in the paper follows:

Unnecessary Accuracy: The perspective of the engineering and accounting departments differs from that of the

managerial. The former tends to exactness; the latter to approximations. The electrical superintendent of a steel mill today is, to my mind, much more of a manager than a chief engineer or auditor, and consequently his mind must deal in approximations, reasonably exact of course, but nevertheless approximations, rather than with exact figures. This viewpoint, his cost division must reflect. The necessary accuracy of the accounting and engineering departments, I believe to be unnecessary in the department cost division. It is suggested that while an accuracy of 1% or better is necessary for engineering or accounting, 5% accuracy should be ample for the cost division under analysis. This, of course, is a general statement and can't be anything more.

The sacrifice of unnecessary accuracy should give time for the study of greater ingenuity in the determination and application of the records. Mr. Huey has stated that accounting department records do not answer his purpose generally. Possibly the reason for this lies in the foregoing explanation.

Time, frequency, and load elements in securing technical data: The life of a piece of apparatus or a part depends on:

The time that it is in use.

The frequency with which it is put in use.

The proportional amount of its rating that it normally carries.

Such other factors as affect the life.

These, I believe, should be associated in arriving at the life factor. It is unfair to judge the life solely from the period from date of installation of the machine or its part to its renewal.

I have not attempted to work out how these factors should be associated, but picture it by applying a system of points, each component to have a determined relation to the whole—that is to the life.

Naturally such a method should be adopted in a cost division only after a careful analysis. Once determined, however, it is simple in application. Undoubtedly, similar arrangements already exist, and the matter is presented purely by way of discussion.

Use of data secured: The paper describes some of the uses made of the data. In addition it might be used as has been done in some bonus arrangement familiar to shop practice, but applied in this case to keep down the expense of renewals, by giving a bonus to operators or caretakers of machinery who reduce renewals to certain minimum standards.

Another use would be to give to the manufacturers information on the life of their product. This it seems to me would be invaluable. Most manufacturers base their designs on general data in their engineering department, plus such actual knowledge from renewal orders, miscellaneous reported and observed information and complaints, as come in. They have usually opportunity to make only approximate life tests under working conditions in their own shops. This data secured in the mill and of record gives practical information of the highest order and I counsel that were it available for the manufacturers, it should result in better apparatus more quickly produced—the end for which we are all striving.

T. E. Tynes: The author has brought out such good arguments for keeping records that there is very little which can be added to what he said, and what I might say would be in the way of strengthening, if possible, his remarks. He says, in substance, any record to be of value should be correct and should be automatic, and I might add should be dated. All of us have probably experienced the difficulty of getting the mill men, when they make a report, to put a date on it. If it is not dated, the conditions change so often that the record may be of no use whatever when it comes to drawing conclusions from it.

Mr. Huey also speaks of keeping track of anything that is of a special nature, by tagging it, and putting on the tags the special features you want the record made up from. That means that someone must be charged with the responsibility of putting those things on the tag of which a record is desired.

Another thing which is brought out, is that in making a record, a proper unit must be chosen as a standard of comparison. For instance, you might have two motors in a mill, and each of these motors have had a part in producing

certain tonnage, but one motor may perform four or five times as often as the other in producing that tonnage, and you cannot judge the life of the equipment by the tonnage produced by it. You must take into account the manner of operation.

Also, as Mr. Pierce has brought out, the record of a piece of apparatus must be judged by its operation rather than by the date of its installation and the date of removal.

Another very important point brought out by the author is that you cannot always get a solution of a problem by one method of attack. For instance, he speaks of some plates, of which an analysis was made, and they showed up the same analysis, but the life of some of these plates was very short compared to other plates, and by a physical examination of the structure of the steel they were enabled to change the structure of the steel in such manner as to bring up the life of the poor plates to equal the record of the good ones.

I am glad he mentioned about the record in keeping track of the lamps, because we have practiced that same method, except that we tag the lamp the day it is delivered to the mill and the mill does not call for it until it goes into service. We tag the date it goes in and the date it comes out, and if it has not burned the guaranteed life it is preserved until the adjuster from the lamp company can see it with its tag and pass judgment on it. In that way we get a mutually satisfactory adjustment.

The author sounds a note of warning as to the danger of carrying the matter of records too far, but as Mr. Lankton brought out we should have a record of the important things first, getting a record of these, and then we can see if it is advisable or desirable to go after the smaller things.

One thing the author failed to bring out is the matter of the value of records to an organization in case of a change in personnel. The man whom you have had for some time has at his fingers' tips all the details of his particular work incident to long service with the company, but when he leaves the company he takes those with him and in such cases the company has paid for service and information for which it is getting no benefit. He should leave his records

and information relating to his work with his successor, who can take up the work where he leaves it off.

Brent Wiley: In order to determine the best method of keeping records, a definite purpose of a record should be first established. A second point of importance is uniformity of data so that direct comparisons can be made in reference to conditions in various plants without the necessity of qualifying the data in detail. At the New York meeting three years ago this same subject was discussed and charts which suggested a standard form of records were displayed. These charts included the principal subject which should be included in the investigation.

It is suggested that the Standardization Committee consider this subject in order to insure a standardization of records.

In most steel plants the electrical departments keep their records of distribution of power, repair costs, expense of store items, etc., in such segregated form that they can be totaled for any particular mill. The mechanical department, as a rule, distribute their charges in a more general way and this is especially so in regard to steam cost. It is therefore important that a common method be adopted by both departments so that all the data pertaining to each individual mill is available.

Information of this character should cover a considerable period to insure that average conditions are analyzed. A short period test often produces data that would be very misleading if applied to a year's operation.

J. F. Kelly: Our records of the mill apparatus cover motors, controllers, armatures, bearings, commutators, field coils, cranes and plow steel cable. In our power house we maintain records of all renewals, oil and waste used on our generating units.

We maintain card records of important commodities purchase, which enables us to follow very closely rises in maintenance costs. Our shops are run on the job order system, common to all plants. We find the job order system to be a good one from the very accurate distribution of labor expended in the repairs and maintenance of electrical apparatus to the proper accounts. We aim to centralize our work as much as possible with the end in view of securing

a higher standing of supervision and personal contact with the apparatus coming in for repairs.

The data compiled in our records enables us to so plan whereby we may make our repairs as economical as possible. Keep in mind that we must not sacrifice workmanship or material in our rebuilding.

Since personal supervision has become impossible due to the expansion of the steel mills, the only reliable way an executive can judge the efficiency of his organization is through a system of periodical statistical reports, which throws the value of records to the operating engineer.

Years ago, the management of manufacturing plants was in the hands of two types of men, the man of purely commercial training, or a bright artisan or mechanic, who, through hard work had forged up from the ranks. Neither man possessing the essential qualifications which constitute the engineer, by their lack of knowledge of the basic principles they were unable to approach the root of manufacturing problems, which accounts for the engineer's entrance into executive capacities. The broad training of the engineer enables him to analyze and determine the causes for any result. His compilation of data provides for the exact deductions and his plans and recommendations are based upon laws, not guesses. Thousands of dollars yearly are spent in the collection of data with the expectation that this data will cause the correction of the conditions studied.

As accurate information and real facts are valuable, when it comes to getting results the manner of presentation is also an important factor. It is exceedingly difficult to convince the minds of others that a proposed solution is the best one, but the Engineer, who realizes the importance of accurate data, develops records and systems whereby he can secure the statistics necessary for an intelligent and logical presentation.

Since Engineering is the science of economical production, cost data in which is shown what the cost is, what it should be, why, when and where losses and waste occur, is absolutely necessary, for when dealing with the cost of production it must be remembered that the price the manufacturer is to receive for his product, and consequently the extent of his profit depends largely upon the exactness with

which he is able to arrive at the cost of production. If the manufacturer's records are such that he is able to demonstrate what his costs are, he is then in a position to meet systematic competition with profit.

Paul Caldwell: Records have long since become recognized as a material factor in the growth of any enterprise and its success in a large degree can be measured by the completeness and accuracy of its records. The value of records in many instances is difficult to determine, for they often have a more far reaching effect than the original purpose for which they were intended. I think this holds true with records of operating engineers.

It is not my intention to discuss "the value of records to an operating engineer", for I am not only unqualified as never having held such a lucrative position, but the subject from that standpoint has been very well presented by the author. I shall endeavor to point out some of the far-reaching effects of such records and to enlarge upon one or two paragraphs of Mr. Huey's paper, which, to me, carry considerable significance.

I was greatly interested in a paper recently read before the American Society of Mechanical Engineers by an official of a large machine tool manufacturer on the subject of "The Commercial Engineer". He described this individual as the salesman who has been trained along engineering lines and whose training especially fits him for handling machinery or other forms of apparatus where a knowledge of its construction, operation and application are requisite to success. He went on to state that practically all new improvements in their machines, as well as the development of new and special machines to meet the increasing demand for greater production and efficiency have been the direct result of the activity of the Commercial Engineer. His reports, based on the records of the machine in the actual performance of its work as compiled by the operating engineer, form the basis for these improvements and new designs.

What this gentleman has pointed out as true with mechanical devices, is equally applicable to electrical devices.

The development of electrical apparatus along designs peculiarly adapted to the operation of steel mill machinery of all types has resulted directly or indirectly from the ac-

tivities of this same "Sales Engineer", with your records as a basic specification. A typical and familiar example is the present-day mill type motor, a machine possessing particularly rugged construction and, as its name implies, especially designed for mill service.

This motor did not spring up over night, but was the evolution of years of experience and experimenting with older designs of motors. Experience as shown by the records of the operating engineers who used them; experimenting on the part of the manufacturers and designing engineers to overcome the weaknesses as they were brought to their attention by these same records.

And what is the ultimate or far-reaching result? Both the manufacturer and the operating engineer are materially benefitted and this benefit can be computed in dollars and cents from the records of each organization. To the former it is represented by increased sales due to the greater demand created for better product, while to the latter it asserts itself in the form of reduced maintenance and less delays in operation.

There is some question in my mind as to where the credit for such developments really belong—with the engineer that actually does the designing or with the operating engineer's records that furnish the specifications.

In the course of Mr. Huey's remarks he makes the following statements:

"Most records not kept in a regular way are left to someone's memory, and after a set of records has been kept it is very interesting to see how exceedingly unreliable, untrustworthy and misleading the memory can be. Furthermore, when the record is left to the memory of some one or ones, a salesman may have good reason to believe that his goods are not getting fair and impartial treatment and, in some cases, it may lead to even more sinister thoughts, but when confronted by actual records, he should have no doubt in his mind that he is being fairly and generously treated. On the other hand, if evidence is not at hand, the salesman may confidently believe that the article will be suitable and economical and he may be right if you cannot argue with any facts to back you up."

I believe most, if not all, salesmen are in accord with Mr. Huey's sentiments and invite the engineer to confront them with the records of their product. They not only invite it at times when purchases are about to be made, but at any and all times, especially when these records show unsatisfactory results or the development of defects in operation. In fact, it is only justice to the salesman, that such records be brought to his attention or at least be available to him before they come to an issue. He is then afforded an opportunity to make the particular article satisfactory or to remedy the trouble and any failure on his part to do so is a warning of what he might expect in the future.

I believe in records and I also believe in the completeness of records. It has been my own personal experience that many good devices are sometimes condemned by the operating engineer either due to lack of any tangible record or by the incompleteness of the records he keeps.

I have a case in mind which came to my attention very recently where a certain piece of apparatus was condemned because it required too frequent renewals of wearing parts and incidentally the cost of maintenance was too high. I endeavored to secure a copy of the record of these renewals and found that none had been kept. On investigation I found that the number and cost of renewals were being compared with a different type and design of device altogether. And further, after a check on the renewal parts was made it showed very favorably indeed and the complaint was immediately dismissed.

Incompleteness of records will often serve to discredit a machine or other device when the cause for the discredit could be found in the missing items of the record.

For example, consider the performance of a mill motor. There are at least two vital factors which have an important bearing on the successful operation of a motor, and especially when attached to some heavy mill machinery where the service is severe and reversals frequent. I refer to the mechanical connection of the motor to its drive and to the control provided for its operation.

Two motors of the same make, design, and rating may be connected to exact similar devices and one perform suc-

cessfully and the other develop mechanical troubles. One may be belt-connected; the other direct-connected. Both may be gear connected, one through a good efficient herring-bone gear, the other through common ordinary spur gears. Certainly the form of mechanical connection has a direct bearing on the comparative results of the two motors and should show in the records.

On the other hand, these same two motors may be connected to the same load in exactly the same manner, and one perform successfully in every way while the other develops electrical or even mechanical troubles. One may be provided with a modern magnetic type of controller designed to protect the motor, and the other with an ordinary manual type with no protective features. Both may be provided with a magnetic controller of the same design, and make too, one provided with a plugging point and the other without. These items should be a part of the records.

Some of you that keep complete records of electrical equipment and watch all these points may think these statements a little over-drawn, but they are based on investigations of actual complaints made by mill engineers. I have known of the back axle shaft of a mill motor being twisted off when no defects in the metal were apparent and subsequent investigation showed conclusively that it was due to defective or improper design of the controller.

Many of us object to be burdened with elaborate records, and I agree they can be overdone. However, we are all working for a common interest—to improve and better our electrical machinery; and it is only by co-operation that any progress can be made. You, the active members of this association, can do your part by keeping your records complete, and thereby automatically design your own future machine, and I believe I speak for my fellow associates when I say we will meet you more than half-way and perfect and build these machines for you as necessity demands them.

Fred. H. Woodhull: I do not know that I have anything in particular to say except perhaps to emphasize a little what has already been said, and that is that reports should be kept complete, particularly as to dates as spoken of by Mr. Tynes, and particularly with regard to records which may be used by someone else at some future time,

great care should be taken to put the dates on these records and to have them complete in every detail. That is a thing that should be kept in mind in making records such as have been spoken of this afternoon.

I have for some time been keeping records of motors, as to the cause of trouble, particularly the armature part of them, when they are repaired, the nature of the repairs done, and by whom they are done, and where the motor is used. In that way I have been able at some future time to install a motor which would give us much better satisfaction than the motor which was originally installed.

L. F. Galbreath: There are three records that are very important in determining the depreciation of a motor.

The hot point temperature of the motor which depends on the room temperature and the load on the motor.

The speed of the motor which determines the number of times a stress is applied to the armature coils in passing the pole piece.

The fibre stress in the shaft which depends on the kind of load and the method used to transmit the motor's energy.

C. S. Ripley: I believe the records that the operating engineer keeps and turns over to salesmen on complaints, interest associate members more than any other point in the matter of records. For instance, complaints are made on certain classes of material, and the salesman puts in his report to the factory that such and such a thing has been giving trouble, and invariably, if you do not send in with your report all detailed facts relating to the matter, they come back saying that unless they have something definite they cannot make any change or comments. They want complete information, and since the matter is to be handled through the salesman, which is the easy way of getting back at the company, the engineer should have this information in his records so it can be given to salesmen in concise form.

C. E. Bedell: There are two points that I wish to refer to, one relating to the record of the life of lamps. It has been stated in one of the discussions that they mark on the lamp the date of installing and removing. This does not give the relative life of different lamps, because one lamp may burn twice the number of hours per day as another lamp, so you do not know how many hours that lamp has

burned, although you do have the dates. Does anyone have a method of trying to get more nearly the actual hours of burning?

The other point is in regard to the records and ought to be considered. A superintendent, in looking over a record of costs, for instance, must remember that the figuring is done, in many cases, by clerks who know nothing whatever of the business, and simply do the figuring. I know that a good many times the superintendent of the department in glancing over the record of costs instantly sees that the record is wrong, and it turns out to be wrong. He knows by experience what the results ought to be, and he knows the conditions under which they have been working, and although the accounting department comes around with figures, you soon find some clerk misinterprets some report coming from the mill, and not knowing the mill conditions he makes a mistake in his figuring, in assuming conditions. So unless we analyze the figures very carefully we may be misled and be very far away from the truth.

F. D. Egan: There is one point on which there has been no discussion, and that is the matter of increasing production by the use of curve-drawing meters. Take the case of the unloading of the ore, blast furnace operation, or operation of a crane in a stock yard, or the production in the blooming mill. A knowledge on the part of the operatives that a curve-drawing meter is recording a cycle of work has improved production in a mill, with which I am acquainted, in the neighborhood of 20 per cent., and we have always found that when any operation was lagging for any reason, if we inserted a curve-drawing meter which recorded a cycle we always found there was an improvement in operation and production.

C. A. Menk: I enjoyed Mr. Huey's paper very much, and think he has covered the subject very well. I believe that every operating engineer should keep records of the most valuable parts of his plant. One of these records I think should be where you are handling hot material, steel and metal in the liquid form.

We have for a number of years kept records of chains and cables, and the loads which these chains and cables are required to handle. To be on the safe side we continually

refer to these records, and not only that, but it has been necessary to show the Safety Committee that we do keep such records and work accordingly.

I do not, however, think that the question of records should be overdone. If it is necessary to hire any considerable amount of additional help to keep the records, I think that would be going to far, and it will eventually become a matter of routine work and under such circumstances the records will not amount to very much.

A great many of these records in regard to repairs, changes, and trouble with equipment, can be kept by your foreman if he is a good man, and after he once starts keeping records, he will be delighted with the results, and will continue to keep such records to show what he is doing and in that way he will be much more interested in his work than if he does not keep any records at all.

I also believe that every operating engineer should keep a complete record of what is going on in his plant. What I mean by that is a record of every kilowatt output in his plant. The time will come when it is necessary to add additional equipment to your power plant and when that time comes there is no use in going to the General Superintendent and saying "I want this and I want that," unless you have something to show why you want it—something that will back up the argument.

Another record which it is important and valuable to keep is of your motor installation. Compare that with your total generating installation. That will have a great deal more to do with getting additional equipment than anything else I know of.

W. T. Snyder: I agree with Mr. Menk that we should not have our system of records so elaborate that it requires too many extra clerks to keep the record. For instance, in the case of the record of an armature breakdown; when the armature is removed the mill foreman writes out a shop order to have it repaired, and then takes out a filing card and writes on that card just what happened to the armature according to his best opinion, and what he would recommend to avoid another breakdown of a similar nature.

That card goes in with the shop record, and that same card, or another card, is filled out by the repair shop fore-

man. He puts his remarks on the same card, telling what he found was wrong with the armature, what he would recommend to avoid such troubles in the future, what he did to strengthen the armature, or if there is some other cause for breakdown, he states his opinion of that cause.

When the job is completed the card is filed in the office. Later on, when you have a bunch of these cards and want to find out how the troubles are running, let a clerk tabulate them and put them in shape to show what has happened in certain classes of machinery and how the trouble has been dealt with.

I believe it would be wrong to give that shop order, when it came to the office, to a clerk and have him go out and interview the shop foreman regarding the matter and have the clerk make the entry on the card. I think that is the wrong way of keeping that class of records. The other way is less work, takes less clerical help, takes a little more time on the part of the foreman of the shop, but you get a statement from the foreman which you can rely upon as being correct.

George W. Richardson: I do not know that I can say much on that line, outside of the fact that I can say that we keep records similar to the system just outlined by Mr. Snyder. The foreman makes up a sheet and sends it into the repair shop, and after the work has been done the shop foreman makes an entry of the character of the repairs and the time spent on the repairs.

On that sheet we have space for the entry of both piece-work and day-work, and the shop foreman makes the proper entry. From that sheet, when it is sent to the office, a calculation of the cost of the work is made and the cost of the job is entered on a card, and placed in a cabinet that is part of our card system, and the record is kept track of in that way. It works very well.

With reference to what Mr. Egan said, as to the use of watthour meters in making tests, I think it is essential to have those things to help out, especially in the case of the master-mechanic. At some of our works the master-mechanic has no way of keeping records of his end, and a great deal of our troubles in the electrical end are caused through conditions in the mechanical end—so much so that it needs

a great deal of argument to convince the mechanical end that this is true. If you have some sort of a record with which you can go to the master-mechanic, and show him that what you say is so, it will help him and it will also help you.

W. T. Snyder: There is another feature in keeping records. There is not only the practical value of knowing what is going on, but there is also a certain moral effect in keeping records. If the men in the mill know they will have to explain every breakdown they will be more careful not to have so many breakdowns.

G. W. Richardson: I know of a mill where this system of records is in use, and they make the records the basis of a system of bonuses, and the system has worked out very nicely. The foreman makes a record of the details of production, and also the number of troubles and breakdowns with machinery, and these are averaged up for six months or a year, and based on these records, a bonus is paid to the men. The foreman also participates in the bonus. It may be ten cents a ton on the production, and on the cost of work and repairs seven and one-half cents, provided the cost is kept down below a certain amount. The owner of the mill tells his foreman that if he keeps down the details below a certain minimum amount of expense, he will have a bonus. He also provides a bonus on the amount of labor and material he uses. It has worked out very successfully, and at the present time the men themselves are making more money, as well as the shop foreman, and he has very little complaint about delays or any other thing.

I believe this is a good system to adopt. It is something which encourages the men to do their best. We have quite an agitation in our plant at this time in reference to time-and-a-half time for Sunday. We cannot overcome it at the present time; but I think if we could start some sort of a bonus system we could overcome a good bit of that argument in reference to time-and-a-half-time, as it is now presented to us. We find that the men on Sunday who would probably have two hours' work to do frequently put in the whole day. If the foreman is given a bonus on his labor you will find that he will take care of that part very nicely and see that the men do not put in a whole day's work

on Sunday when a couple of hours would be sufficient to do the work.

S. C. Coey: I am a strong believer in the value of proper records in industrial plants, as a whole, and especially in large steel plants, but I also believe that it is necessary to use common-sense in the interpretation of our records. Incomplete records and incorrect records are worse than nothing. They simply represent a loss of time and they are misleading.

As an example of incorrect records, or rather an incorrect basis for records, I might cite a system of records that we have kept on belts in a large rod-mill drive. There are four belts in this mill and it had always been the practice to keep records of the belt life on a monthly basis. Some time ago, when we were getting new belts for this drive we found on our monthly basis the life was showing considerable decrease, and on checking things up, we found when we took the tonnage basis, the tonnage of the mill had increased to such an extent that the belts were really giving a better life than they had previously. As a result of that investigation we now buy belts on a tonnage guarantee basis.

When the same records were applied to another installation—I have in mind a 54-inch hot saw—it was found that the belts that did the best on the rod-mill drive did not show up as good as some other belts on the hot saw drive. By using a little common-sense on the subject and investigating it, the fact was easily brought to light that the life of the belt in the case of the hot saw was not a matter of actual life, but a matter of operation.

The tendency today amongst motor manufacturers and manufacturers of electrical apparatus, is to cut down the amount of material used in the construction of the apparatus all possible, which is a natural tendency, as they are in business to make money, and they have to meet competition, and unless the steel mill engineer can show by records to his superiors where it pays to put in more money and get machines of lower temperature rise than are offered, or machines of better mechanical construction, he cannot hope to have better types of machines either built or bought by his company.

Ray S. Huey: Regarding extra help to keep these records, we have found by re-arranging the work somewhat that it is possible to keep these records in the daily routine without any more men at all. Take, for instance, a shop job record; by the accounting department working in conjunction with the shop, we manage to have their timekeeper at the shop take care of the distribution right on the shop record, so that when they get through they have their work all done and ours too.

The effect on the men is very salutary. If they know you are keeping a record they will be more careful to watch the details of the operation of the business very much more thoroughly, and it is the details in every business that count.

Referring to the particular things that are on a test, we always put our order to the storekeeper on it, and we give him a letter when the article comes in, and have him put a tag on it, giving date, order, and other data, so that the man getting the material later on, will have all the information necessary to keep track of any particular article of which we desire a record.

Regarding the question as to how we know how long a particular lamp burns; if the location of the lamp is given the amount of time that that particular circuit burns, we arrive at a very close figure. In our particular mill some lamps burn day and night, 24 hours a day, and others only twelve hours, or eleven hours, according to the kind of weather we have and to the season of the year. On the circuit burning 24 hours a day it is easy but on the others it must be somewhat of an approximation but will be close enough for an average.

COST VERSUS UPKEEP OF DIRECT-CURRENT MOTORS

BY A. M. MACCUTCHEON

The intelligent purchaser of electrical apparatus considers not only the first cost but gives equal consideration to the question of depreciation and upkeep. If it were possible to select a motor with minimum first cost as well as minimum depreciation and upkeep, the problem would be solved and all discussion ended. There is no doubt that it would be greatly to the interest of any manufacturer to design and build such a motor and this is the ideal toward which they strive.

In a well-balanced design, maximum quality is inconsistent with minimum cost and the wise user selects the machine that represents the most desirable compromise between the two for his particular work. The nature of the application largely influences his decision. The ideal motor for driving a ventilating fan falls far short when applied to a threading machine.

Present day practice has already classified to a certain extent. There is the well-known split frame, steel mill motor as distinguished from the commercial general-service motor. Classification can not be carried to an extreme as all standardization would disappear and the balance between cost and quality be destroyed. On the other hand, whenever the demand for further classification becomes sufficiently insistent, the demand must be recognized and met.

No class of service requires a higher quality article than the service in steel mills. Whether general-service motors shall be subdivided into two classes, one high in quality but necessarily higher in cost, can be answered only by the steel companies themselves. "The user must pay." The selling price represent the cost of materials, labor and

overhead with a reasonable profit to the capital invested. As long as the buyer purchases from the standpoint of price alone, the attempt of the manufacturer will be to cheapen the motor as far as possible; with the minimum sacrifice in quality it is true, but the sacrifice will be present. Often the problem is complicated by the natural optimism of the purchaser coupled with the Yankee desire to drive a shrewd bargain. Under the representation of the interested and interesting salesman, whose price is a little lower than his competitor, the buyer wishes to believe that the lower price article is equal in quality and finally decides to take a chance. Still further complication results from the very natural view of the purchasing agent that all material should be secured at the lowest possible price.

In recommending a particular article at an increased cost, the engineer must be sure of the fundamental correctness of his conclusion. It is necessary to carefully balance the higher cost against the extra hazard. The problem is a knotty one due to the difficulty of properly evaluating the cost of repair and possible failure. Here the manufacturer can be of little assistance as the steel-mill electrical engineer should be the instructor and the designing engineer the pupil. In considering the increased cost of the motor to be purchased, the steel mill engineer has possibly lacked detailed information as to the effect on the cost of those features which he may desire and here the manufacturer should lend his assistance. To our knowledge no information of this nature has been published, partly due to the difficulty of segregating the cost of certain features. One change in design resulting in an increased cost may be counterbalanced by another change meaning a decrease in cost.

To make the problem possible of consideration, the assumption will be made that the design is a well-balanced one. The increase in cost resulting from an increase in quality will be expressed as a percentage of the total cost of the motor. The total cost will be referred to as the basic cost, each feature will be isolated from all others. The size of motor selected has an output of 15 h.p at 850 which corresponds to a machine-tool rating of 10 hp. at 400 to 1600. Fluctuation in the market price of material and labor will be *neglected*.

Recent discussion has largely centered upon permissible heating, the consideration of which is beyond the scope of this paper. With increase in heating limits there is no question that the cost of the motor may be decreased without sacrifice of mechanical quality. But it should be borne in mind that the decrease in cost is likely to be secured by rating up each frame size, which means that the decrease in cost is accompanied by a decrease in mechanical quality.

To reduce the heating of the shunt fields in this typical motor five degrees, by the use of extra material means an increase of 1.3% in the total cost. This figure makes no allowance for the possibility of having to increase the overall dimensions to provide room for the extra material. Decrease in the interpole coil of five degrees under the same conditions adds .57%. Five degrees lower heating in the armature penalizes the total cost .7% due to the larger copper used. Here it is impossible to achieve the result only by the use of extra copper. The core must be made larger in diameter or longer which possibly means a further .5%.

A lower core temperature may be secured by using a higher priced and lower loss steel which means .3% for five degrees; or by using a greater volume of the same steel which results in a larger armature. The extra steel represents .3% and the influence of the larger armature upon the rest of the machine .5%.

In the above no consideration was given to the decrease in heating due to improved ventilation. If such improved ventilation can be secured a tremendous saving in material is possible for the same rise. This saving is difficult of evaluation as the question of temperature rise in motors more or less effectively ventilated is the problem in design most uncertain in prediction. To secure some idea, we may consider the fully enclosed motor of the same rating with its 37% increase in cost.

The efficiency is closely allied to heating. A decrease in heating due to a decrease in loss means an increase in efficiency. This increase in efficiency does not result when improved heating is due to improved ventilation or increased radiating surface. It is self-evident that increased efficiency not only lowers the coal bill but makes possible a smaller investment in generating equipment. Information is not at

hand to accurately predict the saving in these two items. However, assuming the cost of power as one cent per kilowatt hour, an increase in efficiency from 86% to 87% on a 15 h.p. at 850 motor operating at 75% load eight hours per day, 300 days per year, results in a decrease of 300 kilowatt-hours or a saving of approximately 1.3% of the basic motor cost. With a pro rata distribution of the decrease in losses, the cost penalty for the 1% improvement in efficiency is 3.3% of the basic cost. An increase in efficiency from 88% to 89% would probably incur a 50% greater penalty.

In the case under consideration, frame material represents 7-1/2% of the basic cost. Decrease in active magnetic material may be secured by the use of a higher grade steel or an increase in shunt field excitation. As compared with the present day practice, the latter method would penalize the cost rather than decrease it and will, therefore, be neglected. The improvement in magnetic quality of steel refined in the electrical furnace is an interesting problem now being actively considered by several steel companies, but the work is still in an experimental stage. The use of rolled steel permits of a lighter frame with equal magnetic quality but no cost figures are available. Considering present commercial cast-steel, no lessening in cost is probable from a decrease in magnetic section which represents 76% of the total frame weight, the remaining 24% covers the frame supports. Increasing their weight by 20% results in a .4% increased basic cost. A liberal eye-bolt over a small one adds .08% and .19% over none at all.

A direct increase of 15% in the weight of the end yoke adds .6% to the cost of the motor. A great deal can be accomplished in lightening the yoke without sacrifice in strength by proper design. U-section arms are practically universal. A large oil well and bearing housing penalizes the cost not only by increasing weight but by shutting off ventilation. A 15% larger housing accounts for a .2% increase in cost, while the effect on ventilation can not be readily estimated. A large size oil gauge and pipe thereto represents but .1% of the basic cost with advantages out of **all proportion.**

As we have been able to interpret sentiment among the steel mill engineers, the pendulum is swinging back toward babbitt bearings. A good babbitt bearing is more expensive than a good bronze one, by 1% of the motor cost. A bearing babbitted with a high grade tin babbitt calls for an increase of .6% over a cheap babbitt. The size of the journal practically determines the size of the shaft and will be considered under that head. Increasing the bearing length by 20% adds .3% to the basic cost.

Proper babbitting jigs, scientific oil distributing grooves and large pressure relief grooves, add only to the cost of the jig and nothing to the cost of the bearing. The retention of oil in the bearing housing where it belongs has received as much study as any feature in the present day design. Drainage grooves, oil throws, and the elimination of suction by windage have quite completely eliminated any trouble and have unfavorably affected cost by .5%. Proper consideration should be given to the decrease in efficiency with an increase in journal diameter and length. At 850 r.p.m., a 10% increase in diameter and length lowers the efficiency but .2%. This slight decrease offers little argument for close design from this viewpoint alone. From the cost viewpoint 10% in journal diameter means 8% increase in shaft weight and .3% cost increase. Ventilation through the armature is unfavorably affected by an increase in shaft diameter. This we will not attempt to evaluate.

The possibility of shaft removal without disturbing the windings is a universal demand among steel mill engineers for which they must pay an additional 2.4%.

If a digression may be allowed, we would suggest for your careful consideration the use of roller bearings as representing an excellent compromise between the rugged oil bearing and the highly efficient ball bearing. Indeed it is a question whether the high grade roller bearing of today does not exceed in dependability the more generally used oil type; as witnessed by the extremely severe usage to which they are subjected in trucks and automobiles. The electrical engineer of one of the largest railroad systems stated that he was actively considering changing over entirely to roller or ball bearings, being influenced to this decision by the unusual record of car lighting units. After three years use, care-

ful inspection failed to reveal any indication of grease in the windings and slight apparent wear of the bearings, while he had found in oil lubricated motors that continued usage showed a great deal of oil-soaked dust in the windings without any direct oil throwing being apparent. The use of roller bearings would increase the cost 4%.

A figure which one year ago would approximately represent the increase in cost for extra good insulation must today be expressed 50% higher due to the unusual increase in the cost of fibrous material. Today we would place this figure at 1.5% of the motor cost. A good baking varnish is a cheap method of improving insulation. An extra dip and bake can be secured at an outlay of .36%. At 550 volts and below mechanical strength and length of life are the most important features of good insulation.

Field coils should be supported between flat surfaces with the line of pressure normal to the supporting surface. The result may be secured by the use of metal coil supports resting in the frame and with a flat surface against the coil. A set of such supports is equal to .4% of the total cost of the motor.

Round wire, because of its freedom from trouble in re-winding and the ease with which it may be secured, is preferred by many. Our study of the cost indicates that no other single feature demands so high a cost penalty, the penalty amounting to 2.5% of the basic cost. When certain sizes of rectangular wire become a standard as is round wire today and when winders become more familiar with its use, we feel that the arguments against it will largely disappear.

General sentiment appears to consider slot sticks preferable to band wire from the insulation standpoint with the feeling that they are likely to break and come out. There should be no such trouble if the thickness of the stick is ample and the notches holding the sticks are deep. An interesting test of a slot stick construction was recently observed on a 1600 r.p.m. machine. The shunt field was accidentally opened, the operator was an inexperienced man, and no overload protection was provided. The consequent over-speeding burst the rear armature band, lifted the coil heads, and wrecked the fields. Since the motor had been run on the test bench at 2700 r.p.m. with no loosening of the

head band, it is reasonable to assume that the runaway speed considerably exceeded this value. Careful examination of the slot sticks showed none broken or split. The use of such sticks requires a deeper slot for the same winding, hence a somewhat larger motor. The exact influence on cost is difficult of determination but is placed at .5%.

Probably no other class of user so generally demands a split bearing at the pinion end as do you. Its advantages in your work are obvious but must be paid for. The increase in cost depends upon the type and we would place it at 4% for the pinion-end alone.

The commutator has been referred to as the heart of the d-c. motor, both because all life current emanates therefrom and because trouble in the commutator will most quickly cause a cessation of all activity. Many a motor continues its existence for a long while with a bad commutator as many a man with a weak heart lives to an old age, but neither is considered a good risk. Mechanical defects will cause poor commutation as readily as electrical ones. We have seen a motor that was sparking viciously have the trouble entirely eliminated by tightening and turning the commutator. Commutator troubles are cumulative, rapidly going from bad to worse.

First considering mechanical features, a 30 degree angle with the same depth of bar affords a better grip than 45 degrees but costs more to machine by a slight amount, approximately .15%. Increase in grip by increasing bar depth $\frac{1}{8}$ -in. raises cost .4%. A riser or tail is a convenience in rewinding and probably results in better first soldering and costs .45%. Increase of $\frac{1}{8}$ -in. in wearing depth must be paid for to the extent of .4%. 5% increase in the number of bars adds to the cost of assembling the commutator and winding the armature .25% of the basic cost. Per pound mica is the most expensive material you find in your motor. Improved creepage distance over the commutator collar of $\frac{1}{4}$ -in. should be charged up at .1%. .035 mica instead of .025 means .6% cost increase. A special varnish treatment in the V is a reasonably cheap form of improving the insulation, as it can be secured at .1% of the motor cost.

Field weakening motors with the relatively small horsepower for the size of frame under consideration, from the

electrical standpoint, need but one brush per stud. From mechanical consideration two brushes per stud may be advisable but penalizes cost 1%.

The use of a rocker ring with the possibility of easy removal and renewal of brush holders and insulation is a desirable feature providing shifting of the rocker by irresponsible parties is made impossible. Over any type of construction of which we have knowledge the rocker represents an increase in cost of 1.2%. The advantage of unshrinkable brush stud insulation, such as condensite or micarta, fully justifies the expenditure of .4%.

There are many points of quality which we have not attempted to evaluate. We wish to emphasize that the figures we have used depend upon a limited investigation and are based upon a comparatively isolated case. These points to which we particularly refer were selected as points on which from time to time, steel mill engineers have expressed themselves as desiring an improvement in quality. We hope there will be a free discussion and criticism which will lead to a better understanding of the demands of steel mill engineers for improved quality and the cost penalty which must be met to secure them.

DISCUSSION

W. T. Snyder: This is the kind of a paper we all appreciate. It is very useful to have such information brought up-to-date, and published in the proceedings of our association. We believe if we had more of such data we would have no trouble in convincing the purchasing agents of our companies of the correctness of our position, and the strength of our recommendation when we want to buy a particular line of apparatus. On the other hand, if we just have a general statement that one piece of apparatus is better than another and have to let it go at that, we cannot expect the argument to go very far, but with such information as this we would certainly have the upper hand of the purchasing agents, because every one of them will buy a

superior grade of apparatus if they can be convinced that it is true economy to buy such apparatus.

James Farrington: In regard to the relative cost of your motors, it might be that you should take into consideration the relative importance of the equipment under two heads; first, the time that the apparatus is running, and second, the time that it is stopped.

If the running time is over 80 per cent. of the actual time, then the cost of the motor is not to be considered. On the other hand, if the running time is 50 per cent. or less of the actual time, the stoppage is of no material importance, and you can take the risk of a cheaper machine.

You must also consider the effect that the interruption of service has on the production of your tonnage. If that actually holds one mill, or in some instances, two or three, where they are run direct from one to another, no motor is too good. As a rule, continuity of service is worth 50 per cent. to 60 per cent. additional in the price of your motor, and not having interruptions, and not having to devote the time of your repair crew to overhauling apparatus which has been interrupted in the service, it gives your repair crew more time to inspect the other apparatus, and in many cases it will cut down the number of spares that you will have to carry to give you adequate protection.

In regard to ball bearings, we had that question up and have made a test on mine locomotives, and we are getting from eight to twelve times the length of life on the bearings on these mine locomotives with ball bearings, that we had with the Lumen bronze, phosphor bronze or babbitt, so that we are changing all of our mine locomotives to ball bearings. We have gotten as high as four years' continuous service on a set of ball bearings on motors.

As to the cost of these bearings; we have an emery wheel made especially for us so that we can re-grind the rings, and we are buying the balls 1-32 of an inch larger than the standard. If the ball wears to a point that is dangerous, we re-grind the rings and insert a ball 1-32-inch larger in diameter, thereby bringing the armature to its correct center.

With reference to the new modern motors above 150 horsepower, I notice that nearly all the companies are using

rectangular wire of closed loops for the primary coils as against the strap coil that was soldered in the front and rear. You could easily repair the burnt-out coil in the old type of front and rear connected in two hours, and have the motor in service again, but in the case of the modern type motors it will mean eight or ten hours' time, if it should be necessary to actually take out the coil, which means the "throw" on the machine each way.

The engineers say that they get better efficiency with this type, and the fact that three of the largest companies are using rectangular wire in enclosed loops seems to indicate the engineers are on the right line, although it is going to affect the quickness with which repairs can be made, unless a spare is carried, which is not generally done on the large motors. It would first appear that we were going backward, when we take into account the time the motor is to be out of service.

R. B. Treat: This paper gives us an idea of producing in quantities a machine having various features different from those of the basic machine selected. It gives us information that has been greatly desired for a long time, and will be very useful in the future, provided we bear in mind that the figures are based upon the production of machines in quantities. This becomes quite evident when we consider a few of the special features. Commutator details offer convenient subjects. Consider that one of $\frac{1}{4}$ " additional creepage over commutator collar costing 0.1%. A new collar mould will be necessary, costing from \$15.00 to \$18.00 depending upon the method of manufacture of the collar. If one or only a few machines are to be built with this additional creepage the purchaser must pay for this shop tool, when paying for the one or few machines. Increase weaning depth of commutator costs \$5.00 for a die to produce the new bar dimensions, and perhaps \$20.00 for a new clamp in which the bar and mica assemblage is baked and machined.

If we consider the special features to apply to only one machine, then not only the tools for making the special machine should be charged directly to it, but all of the clerical work, drafting, and designing on both the machine and the tools should be added. This special machine cannot be

shipped from stock by means of a low priced office routine, but it must receive the personal attention of highly intelligent people. Drawings must be made of the new article and the surrounding objects in order to predict consequential changes in neighboring parts.

The manufacturer's estimate of a change oftentimes seems ridiculously high, but probably in the majority of cases the clerical work is not completely paid for.

The purchaser expects to be able to order a replace part a few years hence, and does not expect to be told that there are no drawings to be found, or that the records are incomplete, or that the man in charge at the time has left the factory.

Special features are oftentimes remedies for troubles experienced. A machine in service may require commutator-turning six times a year, and after eight turnings, a new commutator becomes necessary. The new commutator may be ordered with double the turning depth. It may be that the first commutator was baked improperly in the original manufacture and thereafter performed badly. The brush rigging may be at fault. The first commutator may have been loose on its shaft. Of course there are any number of possible reasons for the original trouble. Perhaps the new commutator will never require returning, in which case the special depth of the bar is unnecessary. Perhaps the inherent commutating properties of the machine are bad. Whatever it is, a big black mark should be made against the machine, and remembered when contemplating the purchase of similar ones.

There is a great risk in buying machines having special features. Those features are departures from the factory practice, and they introduce unexpected questions throughout the entire manufacture.

Let us assume a requirement for 30-degree angle on the commutator bar, and that the factory has, heretofore, always used 35-degree, also that the factory makes good 35-degree commutators, because the collar mould and V-boring gauge have been brought into agreement through shop experience in spite of draftsman's figures, knowledge of mica board shrinkage, etc. The order for a 30-degree "V" is executed in the factory by men who never heard of the shop

experience on 35-degree "V". A commutator is produced that is just as bad as the first 35-degree "V" ones produced years ago. The customer gets a bad commutator, when he easily might have gotten one from the same factory, made by its tried out and customary methods and designs that might be superior to any commutator made by any factory.

I wish to emphasize the following:

A feature from one manufacturer that gives excellent results on his product may produce bad results when affixed to another manufacturer's product. The feature may be an excellent one, but one shop may know how to use it, and the other may not.

It is bad practice to insist upon one shop producing special machine features that have been well produced by another shop.

If troubles are annoying, and must be reduced; good features are evident in some machines, and desired in others; improvements are thought possible over what at present is only good enough—then talk it over with the motor manufacturer, and his men in whom you have confidence.

My attitude in the matter of a new operation in a shop, or a new product brought out by a manufacturer may be well shown in my general answer to friends who ask my advice or opinion upon a newly produced automobile. My answer is, "Don't buy or accept as a gift a newly produced auto until it has been on the market a year, and the second year's product is advertised as having only slight changes from the previous year, even though the manufacturer has been in business for years." An auto or an electric motor may be reproduced, on drawings, in a second shop, and the result may be a bad output.

The author's paper is excellent, provides excellent data, but use it principally as a basis of comparison of machines of existing manufacture in determining the relative value of them, such for instance, as one make of machine might be worth \$200.00 while the other with $\frac{1}{4}$ " greater commutator collar creepage should be worth \$200.20.

Fred B. Crosby: I had no intention of being drawn into the discussion of this particular paper, but in his statement relative to the status of the designing engineer Mr. MacCutcheon struck a responsive cord.

There is an inevitable difference in the point of the designing engineer and the commercial man. The aim of the former is to produce the best possible device from the available material. As a rule he prefers to keep a little up his sleeve so that when the machine comes to test it will show up a little better than his original guarantees. The tendency is often to sacrifice practical to theoretical considerations. The commercial department obviously exists for the purpose of selling the manufactured product. In the effort to accomplish this purpose there is often a tendency to overlook the fact that continued sales can be reasonably expected only so long as the product comes up to a recognized standard.

Our organization recognizes this difference of viewpoints and provides a general engineering section, the primary function of which is to study prospective industrial applications from every angle of theoretical design, operative requirements, and possible commercial value, to pass an impartial judgment and bring the necessary pressure to bear upon opposing interests.

The rapid growth of electrical manufactures has brought into common usage a relative new word, "obsolescence". It is not practicable commercially to build a machine so good that it will never wear out. Methods of manufacture improve and new materials are discovered or produced synthetically. Equally good and often even better devices can be produced for lower cost than existing designs. Greater operating economies often render replacement advisable long before equipment is worn out. It is obsolete. Steel-mill engineers sometimes object to the frequent changes in designs offered by electrical manufacturers, losing sight of the fact that these changes, while causing them some annoyance, are a hundred-fold more objectionable and expensive to the manufacturer. It is largely for you to say which you will have, competition, new designs, and lower cost or unchanging standard designs at old prices. The steel-mill engineer faces a perpetual problem of how to obtain the most effective compromise between the factors of first cost, maintenance, and efficiency of operation.

R. W. Davis: The majority of the items brought out in Mr. MacCutcheon's paper are considered standard and

are furnished by steel-mill motor builders. There is no question but that the best motor for steel mill service will be obtained when designing and operating engineers co-operate to produce a machine to meet the given service conditions.

The large users of rectangular wire have made an attempt to standardize on certain widths and sizes. These standard sizes are carried in stock, both bare and double-cotton covered. When an order is received for spare coils the wire can be drawn from stock and the coils delivered in a comparatively short time. Many steel mills keep certain of these sizes of wire in their own stores and make their own spare coils.

L. F. Galbreath: I do not know that I can add very much to the discussion although I may bring out one point. Suppose we consider two motors which have the proper characteristics for two duplicate machines on which they are to operate. One of the motors is a low first-cost motor, which has a short life, therefore it will produce a large number of hours delay per year, which results in a small production at a high cost per ton. The other motor which is a high first-cost motor will have a longer life, therefore a smaller number of hours delay per year which gives a greater production at a smaller cost per ton. As the difference in price of the two motors is small compared with the earnings from the increased production and the earnings due to the lower cost per ton of production, the high first-cost motor will produce greater dividends.

Clark S. Lankton: One point Mr. Farrington brought out, that is a motor that had 50 per cent. operation might be a somewhat cheaper motor than one which had 80 per cent. operation, apparently seems to be very good logic. On the other hand, the steel-mill engineer has to standardize to a great extent, and he has to keep the motors as near alike as possible, so that if there are places where the 50 per cent. operation motor could be used, there are undoubtedly other places requiring heavier service, and in order to keep the motors all alike, you have to provide the better motor for the lighter work.

John C. Reed: Mr. Farrington's remarks on the use of ball bearings are very interesting. I have thought for

some time that we should come to a point where we could get longer life out of the motor bearings, and the use of ball bearings seems to be a step in that direction. For a number of years I have used in one of our departments, a number of small motors which have ball bearings on the commutator end, and a few weeks ago we had trouble with the first one, after something like four years' use, so I am inclined to believe that ball bearings in the smaller line of motors would be superior to the babbitt bearings.

W. T. Snyder: I wonder what influenced Mr. Farrington to use ball bearings or roller bearings? Did Mr. MacCutcheon evaluate the speed? What is the difference in the value of a 7.5 horsepower motor, 500 revolutions, and one of the same horsepower at 600 revolutions?

T. E. Tynes: One of the gentlemen made the remark that if the steel mill engineers would only tell the motor manufacturers what they wanted the motor manufacturers would try to give it to them. I have been trying to tell them for the last three years that what we want is a standardized motor, something we can depend on and will not be changed in a few months. I can recall in the last ten years one line of induction motors which has been changed five times and we have four of them. The result is we have a collection of antique motors, the parts of which are hard to replace when we need them. The earlier motors were well made and stood up in good shape. I do not see the necessity of changing designs so often when we are willing to pay for a good design and stick to it.

I think the first requisite in a motor for steel mill use is reliability of service, and we are willing to pay for that kind of equipment, but we do not want to be penalized two or three years afterward by having to buy repair parts for the old motor at a greatly increased price on account of its being obsolete.

If it comes within the province of this Association to get up a standard mill-type motor that we can demand from the manufacturer, I would be in favor of such a motor. As the quality of the material increases in permeability or in any other way, put that material into the motor, but arrange matters so that we can secure duplicate parts at all times

and not be compelled to carry a storehouse filled with a miscellaneous assortment of motor parts.

W. T. Snyder: If there is any one point the steel-mill men are unanimous on, it is the point Mr. Tynes has just brought up.

Ralph H. Kilner: There are two sides to that story—the side of the steel-mill man and the side of the manufacturer. Mr. Tynes prefaced his remark in substance “If you standardize on a good motor, we will pay for it.” The experience of the manufacturer is that the steel-mill men will not pay for it. The manufacturer brings out motors just in line with what the steel-mill men want, and while the steel-mill men may be willing to pay for it, the purchasing department of the mill is not. The manufacturers bring out machines having the characteristics of interchangeability, exchangeability and ruggedness that the mill owners want, but our experience has been that we cannot sell enough of these machines to justify the continuance of their manufacture, and that is the reason why the manufacturer of steel-mill motors has to change the design. You want both cheapness and durability in the same motor, and we cannot always reconcile those two elements.

It was the experience of one company to bring out a good machine, which the steel-mill men wanted, but they were not able to create a sufficient demand for this particular machine to keep it on the market.

T. E. Tynes: This matter comes back to the question of records. If you keep actual records you can go over the purchasing department, to the general superintendent, and if you can show him a saving in dollars and cents, you will get a good motor.

C. E. Bedell: Mr. MacCutcheon, in his paper, has dealt in considerable detail with the various elements entering into the design of a typical motor, and showing us the effect of the various improvements on cost. This, of course, is quite a help to the operating engineer in knowing what qualities are most desirable for a given first cost. But, as hinted at in the second paragraph of this paper, it is the purchaser and electrical department that are vitally interested in the selection of a certain motor to a particular application, and the decision must be based on the relation the

motor bears to the complex system of manufacture to which it is being applied. In this system the motor is one of the component parts having a definite responsibility with relation to the cost of operation and in turn the cost of the finished product. It is then the problem of the electrical engineer to so select his equipment as to gain the best results, both in operation and repair at the minimum of cost. He is not hampered by lack of variety to select from, for, thanks to competition, the manufacturers have produced a great variety of types as to quality and cost. But it is about as difficult to judge a strange motor as it would be a strange man. It cannot be done by rule or weight but by experience in service, and it is a question of making good on the job. So in the discussion let us consider the relations existing between first cost, upkeep and the operating importance of the motor as related to the cost of the finished product. It is just as important for us, in purchasing, to harmonize the motor characteristics with the related features of the complete installation as it is for the manufacturer to select the component parts of a good well-balanced motor design.

Now, suppose the typical motor of 15 h.p. used in the paper under discussion is an average trimmed down motor, but meeting average specifications, and that we make all the improvements suggested in his paper we will then have a motor costing about 20% more than the original motor and of course a better motor. Any manufacturer can make a better motor if he can get the price for it. The question is, shall we demand it for all applications and shall we spend the money for repairs or first cost? At this point we must consider the relation the motor bears to the rest of the operating features including men, machinery, and overhead expense. In order to illustrate the principle involved, let us consider the extremes in our classification of manufacturing processes for which we are to select the most desirable motor. Let us consider the classification as follows:

Class A. Finishing departments where the number of men corresponds with the number of motors, and each equipment independent of the other, such as any individual machine drive, machine shop, or threading floor of tube mill.

Class B. A process where power cost is small, wages high but continuous operation very essential such as tube mill furnaces.

Class C. A process where power and first cost of equipment are high with wages minimum.

With these three classifications we can more readily see that the same class of motor would not be applicable in each case. Now, consider the 15 h.p. motor in question, and apply it to class A with 100 men and 100 machines. If the motor cost \$225.00 we would have a first cost of \$22,500.00 for motors, and for the improved motor \$4,500.00 additional would be required or enough to buy 20 spare machines. A motor delay of one-half hour here is not an expensive delay, say thirty cents. So in this case it would seem that the higher priced motor is hardly justifiable.

But, in the case of Class B, application such as a tube mill butt weld furnace having eight motors totaling 100 h.p., at a first cost of \$2,000.00, a power cost of 25c per hour, a labor and overload cost of \$18 per hr., a half-hr. delay here means \$9 actual, a proportionate loss in production and indirect effect on the quality. So in this case the efficiency of the motors can well be sacrificed if it will add the least to reliability, and in this connection we should remember that the commutator and brushes are the places to spend the money when reliability is paramount. In this class of service a failure of any part of any motor affects the whole process and total production in the direct ratio of the time required to get back to service again, so it is obviously penny-wise and pound-foolish to economize on motor details that will in any way deduct from the reliability of the motor.

In consideration of Class C, such as a motor-driven blooming mill, the condition requires an entirely different basis of thought. Here the first cost is high, also the power cost, but wages are a minimum. These figures may be as follows: First cost, \$150,000.00, a power cost of \$2.50 per hour, a stand-by or constant cost of \$4.40 per hour, making only \$1.00 cost against one half hour delay, because of power being shut off. Here strength and reliability are important, not so much from the cost of short delays, but because any break is likely to be expensive on account of its

size and the replacement requiring long delays. The feature of equal importance here is efficiency, as the power item over-shadows any other single item, and is a large part of the total. In this class of equipment the repairs should be practically nothing for long periods as when they do come they are generally large items..

These few remarks are only to emphasize the fact that the questions of repair as related to first cost are equally related to the associated conditions of the installation and should be judged according to the part they are to occupy in the complete system of equipment and can not be determined upon when separated from these surroundings.

D. M. Petty: I think one point to be considered is the commercial end, reliability and efficiency. Efficiency of the steel mill motor, with low cost of power, is not as important an element as the reliability. Since the efficiency of the machine is materially affected by cost, it seems to me it is not always necessary to buy the most expensive motor, especially a motor whose increased cost was made up primarily to secure greater efficiency.

A good part of the troubles with motors is due as much to mechanical as to electrical defects, and the majority of the electrical troubles lie in the commutator. I feel that the manufacturers can well afford to spend money in making motors, and the steel mills can well afford to spend money in buying motors that have good, rugged commutators and brush-holders that are put on mechanically strong. A flimsy brush-holder can spoil a motor having all the other good points in it that money can buy.

A further point about efficiency, on such motors as crane and table motors is that the total running time of the motor is comparatively small, and therefore the efficiency may be considered as of minor importance when compared to reliability.

J. E. N. Hume: In line with what Mr. Tynes has said regarding changing so often, I think if you will look back over the past you will find that there has been a very good reason for these changes, and that when a change is made the manufacturing company has to go to a vast amount of expense incident to the new design and construction of the motor, in educating the salesmen to the change and, in-

identally, in changing its price books, etc. These changes would not be made unless there is a very good reason for them and the reason is almost invariably due to the fact that the manufacturing companies have a better design to offer, and incidentally, very frequently the price is somewhat lowered by the new design. I think you will find, in this fact, the reason why automobiles are changed yearly, namely, to keep them on a competitive basis. It is not that they make promiscuous changes just merely for the sake of changes, but these changes are made absolutely for the purpose of keeping the manufacturer in a competitive position and to offer something better to the public.

J. E. Brobet: Mr. MacCutcheon's paper deals very thoroughly with a subject which unfortunately is fully appreciated by only a small percentage of salesmen and purchasing agents and too great an effort cannot be made to bring the points dealt with to the attention of the buying public.

One particular feature in design of motors which will materially affect Mr. MacCutcheon's data and which a motor manufacturer must carefully consider before introducing a new line of motors is the relative cost of raw material, particularly steel, iron and copper.

With relatively low cost of copper the design would cover what may be termed "copper" machines and which would result in unusually low weight. This, however, does not imply that the machine would be more efficient, or that heating would be lower, but the percentages for various changes would differ somewhat from those given, being higher in some cases and lower in others.

Should the motor manufacturer aim to build motors which will have a minimum cost dependent on successful operation on each of various load applications such as pumps, fans, line shafting, etc., he would arrive at a condition where he would be burdened with so many different designs both mechanical and electrical that it would be impossible for him to manufacture any one of them economically.

It has, therefore, been the custom of the General Electric Company before exploiting a new line of motors, to carefully consider the requirements of the various applications and so design the "standard" line of motors that

it will embody as many of these requirements as is consistent with cost and percentage of sales, only slight modifications being necessary to adapt the motors to special service conditions.

It has been found necessary, however, to deviate from this course in one case; viz., that of the adjustable speed motor primarily designed for machine tool work. The duty requirement for this work differs so widely from that of the usual constant speed motor that it has been found necessary to design a line of motors particularly adapted to machine tool work, always remembering that a machine tool "equipment" means a combination of motor and control and that it has been found advantageous to simplify the control equipment as much as possible even to the extent of placing an additional burden upon the motor in the shape of better commutating characteristics, this in turn resulting in a somewhat lower relative cost of control, a higher cost of motor, a much lower maintenance cost, for whole equipments, and better general operation, exceptionally good electrical operation being combined with rugged mechanical design.

As good electrical operation and long life go hand in hand with high efficiency, the efficiency of such a line of motors is consequently high in comparison with an ordinary constant speed line in which the question of overloads, variation in speed, no load to full load, low heating of fields with motor armature stationary, etc., are not so carefully considered. Mechanically such a line should be very rugged, should have split rear end shields for ease of removing armatures when geared, and of as small physical dimensions as possible; the latter point being exceptionally important.

All of these features mean, as Mr. MacCutcheon has pointed out, additional cost above the minimum cost of motor which would "get away" in a majority of cases, particularly where the duty requirement has been overestimated and the tool over motored, and prove unsatisfactory from a standpoint of electrical and mechanical life in those cases which put the motor to a real test and which are becoming more and more universal.

The mechanical construction and special parts of such a line are always available for use in special constant speed applications where the requirements will warrant the additional cost.

W. T. Snyder: I do not know whether I can speak for Mr. Tynes or not, but speaking for myself, I do not think we take the stand that we want the manufacturers to stop developing the motors, but what we would like to have them do for instance, is to keep the over-all dimensions the same, so that an improved motor will fit where the old type of motor was installed, and keep the armatures interchangeable, so that we do not have to get a complete line of spares for every improvement that is made.

John E. N. Hume: Most of the companies try to do that, but there are numerous cases where they can not do it.

George W. Richardson: With reference to the paper under discussion, I might say the larger wearing depth of the commutator—that is where we have most of our troubles in our direct-current motors—appealed to me very much. At our place, we make quite a number of changes ourselves; that is, when we find a commutator that has not very much wearing depth, and which after it has been in use for a year or so is wearing out, we make another commutator with larger wearing depth. We also often find that the insulation between commutator bars is so thin that the grease and dirt we have in the plant causes a great deal of trouble, and we have increased that thickness somewhat. We have also taken the front end off the commutator as well as the back end and put on a mica ring clear up to the wearing surface of the commutator. In quite a number of places where we had considerable trouble from the oil and dirt we found that the armatures and commutators were wearing much better by reason of the changes that we made, and which I have just indicated. Sometimes we have a little trouble in holding the rings on.

We make quite a number of armatures and insulate them quite heavily, but we have considerable trouble with the dirt and oil that goes onto them.

In reference to the bearings, of course our machines are old-timers and it is a hard matter to keep the oil in

the bearings. Many times in machinery connected by gear, the back-lash stirs the oil, the oil siphons, and runs out of the bearing. You may ask the man in charge of it and he will swear that he put the oil into the bearing the day before, but the bearing is stuck or cut out due to the oil siphoning out.

Some years ago we had considerable trouble with motors that are obsolete at the present time, and we were doing reversing work with ring-wound armatures. I changed them to a form-winding, using the same cores, increasing the shafts and also the bearings, and at the same time I made up the commutators of large-wearing depth; and I must say they are the best open motors I have around the plant, not taking the new mill-type into consideration. It is very seldom that we have any trouble with them. We use them on the same work as formerly. The improvement was entirely due to changing from the ring-winding over to the form-winding, and the commutation of the motors at the present time is better than before. This improvement was brought about merely through ordinary repair-shop practice. I think we have made the commutation a little better by using the form coil instead of the ring-winding.

E. L. Behrens: There is one point which has been very forcibly brought to our attention lately and that is the deliveries of motors. We tried very recently to get a number of these "good" motors, and we could get nothing but a promise of delivery in nine months. We are moving pretty fast in our business just now, and we could not afford to wait this length of time.

The standard motor as it has been developed is pretty generally applicable, and where difficulties are experienced due to the standard design, we have found they can be minimized by giving a greater attention to methods of application and the details of maintenance. As a single example, I might say that daily inspection is made without disturbing the large cover of bearings, because by so doing a small amount of grit invariably finds its way into the bearing. While in a great many instances we would prefer to use a motor more adapted to conditions as they exist, we are really performing miracles by our use of the stand-

ard motor. When any trouble is experienced we endeavor, by careful study, to ascertain its cause and to remedy it on the ground.

W. T. Snyder: Mr. MacCutcheon said that "the dielectric strength of insulation is not so important in 250-volt apparatus."

My remarks earlier in the session about having to ship a piece of apparatus back to the factory was a case where the insulation failed. The manufacturer would not believe it, because the apparatus had stood a test of 1500 volts at the factory, and had been subjected to only 250 volts at our plant.

Ordinarily the insulation is amply safe, as far as the dielectric strength is concerned, but there is not sufficient creeping surface and the current finds an easier path to ground than through the insulation.

James Farrington: The President asks why we use ball bearings instead of roller bearings. In this case the bearings were applied on a Jeffrey locomotive, and the space allowed for the bearings was too small to get roller bearings of sufficient carrying capacity on the apparatus.

A. M. MacCutcheon: The point brought out by Mr. Farrington was very interesting, namely, that in the case of the 80 per cent. running motors a higher cost was warranted, and in the case of the 50 per cent. running a cheaper motor was justified. That is the kind of figures we have not had, and it is the kind of figures which is interesting and helpful in reaching decisions.

Regarding the length of life of the ball bearing as compared to the oil-ring bearing, it has been our belief, though it may have to be corrected by information which you gain based on your experience, and that has been given today by Mr. Farrington, that the ball bearings stand up better, require less attention and will not go down from lack of attention nearly as quickly as the oil bearing for all the uses to which the bearings may be put. That is the point of view of the manufacturers on that proposition.

I know some of the large companies today are bringing out what they call a heavy-duty bearing, and now they are going even further and making a steel ball bearing,

which they call their mine locomotive bearing, a geared motor-drive bearing. In this case the great difference between what they called the heavy-duty bearing, and now term the mine bearing, and the geared motor bearing, is in the construction of what they call the cage—the material of the balls was not at fault, it is what holds them that went down.

With regard to Mr. Treat's discussion, he has made a very strong point, indeed, on the interchangeability of parts. He covered quite well the point which was later brought out, namely, the undesirability of frequently changing designs and the consequent lack of interchangeability. The only comment I can make in that connection is that all companies do more or less re-designing. I am not particularly prepared to urge any particular customer to ask for high quality features which the motor otherwise would not have, for that one installation. If he does that Mr. Treat's criticism is justified.

What we try to bring out in the paper is the desirability of the motor manufacturer knowing just what you need, your advising him as to your requirements, and he, on the other hand, telling you what these requirements will cost, so that when a motor is re-designed you will know what it will be sold for, and what you will have to pay in order to procure it.

The paper suggests a heavy-duty motor for general service work, in between the motor sold for printing presses and other work of that kind, and the type of motor supplied for blooming mills, etc., that motor to be standardized and manufactured in quantities.

It has seemed to me in considering the subject of the paper that there is a large demand from steel-mill users for a heavy-duty motor for general service work, even at an increase in cost.

Regarding the actual cost of tools to give these special features, as cited by Mr. Treat, the tools being rated at \$53 on 100 motors, that would make it 53 cents on each motor—I am talking about motors that will be manufactured in thousand or ten thousand lots, and therefore I claim that the point of expense in the new tools would be

quickly wiped out if the features are made standard for a standard line of motors for this particular line of service.

That viewpoint answers the criticism that one manufacturer, using a feature found to be good, but differing from his past practice, might not successfully carry out that feature.

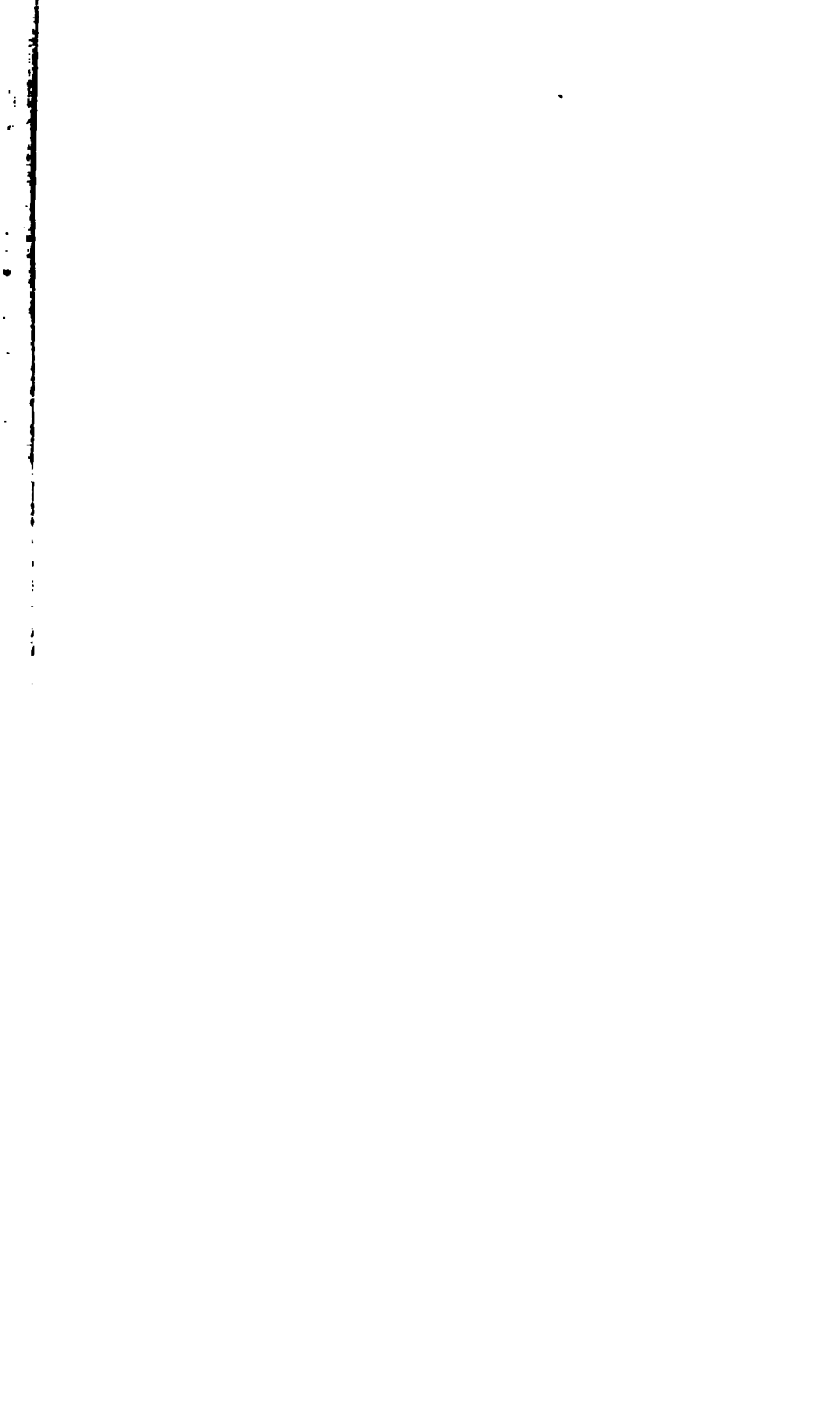
Mr. Davis referred to the standardization of rectangular wire. I was looking at it a little differently from what he was. He referred to the fact that the companies standardizing on windings use the rectangular wire. They do; they are going further, and extending the standards of one company to become the standards of all the companies. They have standardized on round wire, and there is no reason why they cannot standardize on rectangular wire, except that it is possible to get so many combinations. The steel-mill men are adding their influence to that of the manufacturers, and are endeavoring to influence all manufacturers to get together so that wire can be carried even for motors manufactured by different companies.

I think Mr. Lankton's point was interesting on the undesirability of having two types of motors, one to meet the 50 per cent. operating condition and one to meet the 80 per cent. operating condition. We must give careful judgment to the answer of such a question, especially when we are considering the desirability of having a standard uniform motor, even though in certain cases you get away with the 50 per cent operating motor, which would be a cheaper motor.

On the difference of speed as affecting the difference in cost, I did not touch on that, as you already have a pretty good outline on the effect of speed in relation to the difference in cost. The price lists, which are always available, give you the price of the motors in relation to their speed. That is a subject which might be covered more in detail in a paper presented by some other author on information along the cost line. I would be glad to contribute to such discussion.

I will point out that the Power Club, an organization of motor manufacturers and electrical appliance manufacturers has already taken very strenuous steps toward standardizing motor speeds and temperature as far as possible.

Mr. Behrens referred to a recent case where shipment could not be made within nine months. I am sure that you will appreciate that no one regrets this condition of backward shipments more than the motor manufacturers. In several cases the manufacturers could produce that motor in practically the same time that they produced it a year ago in their factory, due to the fact that they are working night shifts, with highly efficient methods, etc. The whole trouble is in getting material from the copper people, the insulator people, and the work is hampered by strikes in iron foundries. After waiting three months on a promised shipment, we manufactured the motor in 13 days after we received the last material.



MECHANICAL AND ELECTRICAL OPERATION OF THE HEROULT ELECTRIC ARC FURNACE

By G. W. RICHARDSON

Mr. James H. Gray of the United States Steel Corporation, in his notes on Electric Furnace construction and operation in a steel foundry, says that as a simple competitor of coal or gas in furnishing heats for steel making process, electricity is expensive. The electric furnace however, furnishes a means of producing steel under conditions free from the contamination of oxides, and therefore makes possible chemical reactions and metallurgical operations that cannot be realized by the older methods. In the arc-type furnace, the heat is applied by an arc or arcs playing into or above the bath and in this type of furnace, the slag is hotter than the molten metal beneath it, that is, by keeping the slag hot, the heat induction heats the metal.

Therefore the construction of Heroult Electric Furnaces that our company builds is of the round type up to 3-ton sizes, and the 6-ton sizes have been of the elliptical rolling type, but we are now building 6-ton sizes of the round type, and have designs out for up to 15 and 20-ton furnaces of the round type. The round type in my opinion is, and would be, preferable.

Fig. 1 shows the sectional elevation of the first 1-ton electric furnace that we built, which is still in use and giving very good results. When we installed this furnace we figured to get heats out in approximately four hours, so that we only installed 225-Kv-a. capacity, three 75-kv-a. transformers 2300-100 volts. We connected the transformers in "Y" primary side to operate on a 2300-volt service. The secondary connected in "Delta" for 100 volts at the

terminals. The operators of this furnace soon found out that they could get the heats out quicker by using more current, so they operated the furnace overload up to 300 and 350 kv-a and are doing so ever since, getting out from 8 to 10 heats per day of 24 hours. This experience soon told us that we could increase the capacity of all the furnaces so that we practically doubled up the kv-a. capacities. You will note that we run the electric cable over to the electrode holders. We found this to be bad practice, so we had to place bus-bars from the electrode holders, running

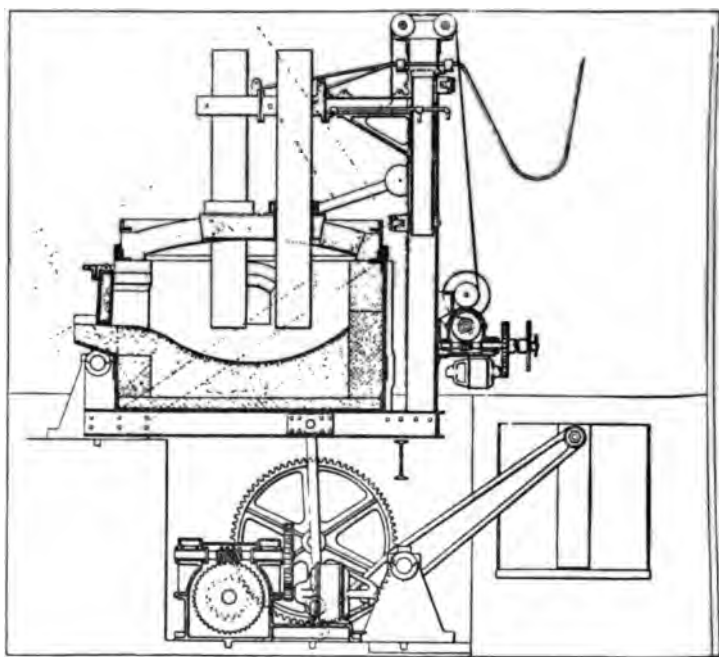


Fig. 1

them outside of the furnace mast, then connected the cables to these bus-bars, which gave much better results. We use a spur and worm gearing to raise and lower the electrodes, arrangements being made to work by motor or by hand-wheel. The hand-wheel is placed for emergency in case the motor would become defective. The operation could be accomplished by hand until the heat was finished, when repairs to the motor could be made. The raising and lower-

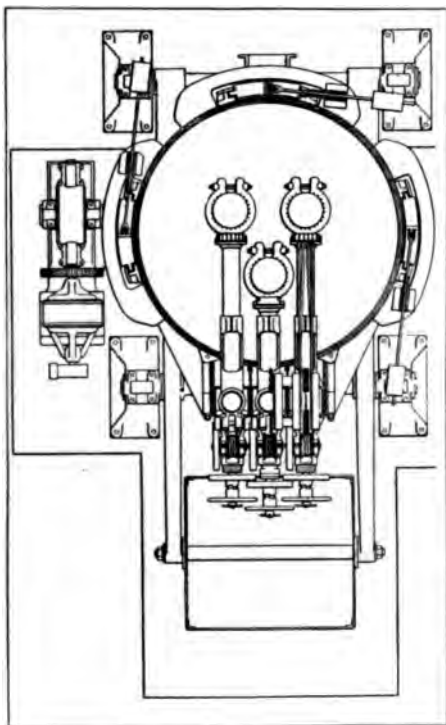


Fig. 2

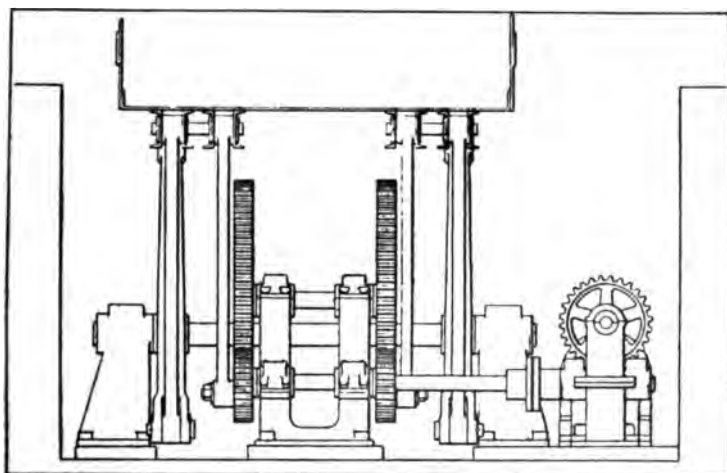


Fig. 3

ing of the electrodes is done by steel wire rope, one end fastened to the bracket carrying the electrode holders, the other end run over a sheave and fastened to the drum. These electrode brackets run on guides and so braced to keep them in line so that the electrodes slide through the copper coolers, and through the roof. These electrode holders and coolers are water-cooled.

The tilting mechanism is shown below. The motor geared by spur gearing to a worm gear which in turn is geared by spur gearing to the crank rod, which lifts the furnace and load up at one end. The furnace is pivoted at the fulcrum near the pouring spout. The tilting mechanism also has a beam which carries a counterweight made up of an iron box filled with punchings or pig iron. This counterweight acts to take off part of the starting load on the motor, and gives easy manipulation of the tilting mechanism, so that pouring can be done in hand ladles if so desired. By this style of tilting the furnace cannot upset. It will go so far and then lower again.

Fig. 2, shows top view of a 3-ton furnace with a door at the pouring spout, and a charging door on both sides. Also shows how the electrode holders are made and fastened.

Fig. 3, shows detail of the gear train and machinery for tilting.

Fig. 4, shows the Seede automatic electrode regulators for a 3-phase, alternating current furnace. The top panel shows the d-c. shunt contactors for operating and reversing the direct current electrode motors, also the dynamic braking contactors. The center panel shows the three contacting ammeters which regulate the electrode motors according to the amount of current flowing. These contacting ammeters have small lever attached to the plunger of a solenoid, so to make the connections for the shunt coils of the armature contactors. The setting of the contactor ammeters for the different amounts of current is made by small hand-wheel below. This cuts in or out different layers or turns on the solenoid. These contacting ammeters are enclosed in a separate case and after they are adjusted for the furnace, the case should be locked so that no one can make adjustments he thinks should be done, without notify-

ing the electrician in charge. After once adjusted, they should and will operate properly for a long time without any additional adjustment. The lower panel shows the three potential relays, that while everything is working alright, these relays complete the d-c. circuit to the lever on the contacting ammeters, but if an open circuit occurs—that is if an electrode would stick and open one phase—the



Fig. 4

relay would release which would stop all the electrode motors, or rather break the d-c. circuit to the levers on the contacting ammeters which also helps to protect the oil switch from opening, that is when the dynamic braking is working properly. If the breaking resistance is too high, the electrode motors will continue to revolve after the circuit is broken, which allows the electrodes to drift, and will

open the oil switch, but if the resistance is adjusted so that the motor stops almost instantly, there is not much danger of opening the oil switch often during a heat.

Fig. 5, shows the back view of this regulating board. The instrument panel is always placed alongside of the regulating panel. The instrument panel contains one voltmeter, one power factor meter, one curve drawing wattmeter, and three indicating wattmeters, all on the top panel. Indicating ammeters could be substituted for the indi-

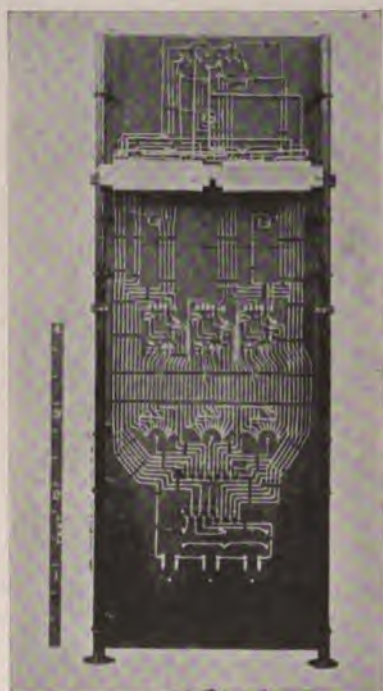


Fig. 5

cating wattmeters if so desired. The center panel contains the voltmeter plug for testing the voltage on each phase, and the hand-operated or solenoid-operated mechanism for operating the oil switch. The lower panel has the time relay for the oil switch and one watthour meter. The push-button board for starting and operating the furnace by manual control is placed in front of or to one side of the

instrument board to permit seeing the instruments plainly.

Fig. 6, shows the wiring diagram of the electrode motors.

Fig. 7, shows the table we use, giving size of furnace kw-capacity, amperes per phase, etc.

Fig. 8, shows a 6-ton rolling type furnace which gives a very good view of the front of the furnace including the base. You will note also the switchboard is all housed in,

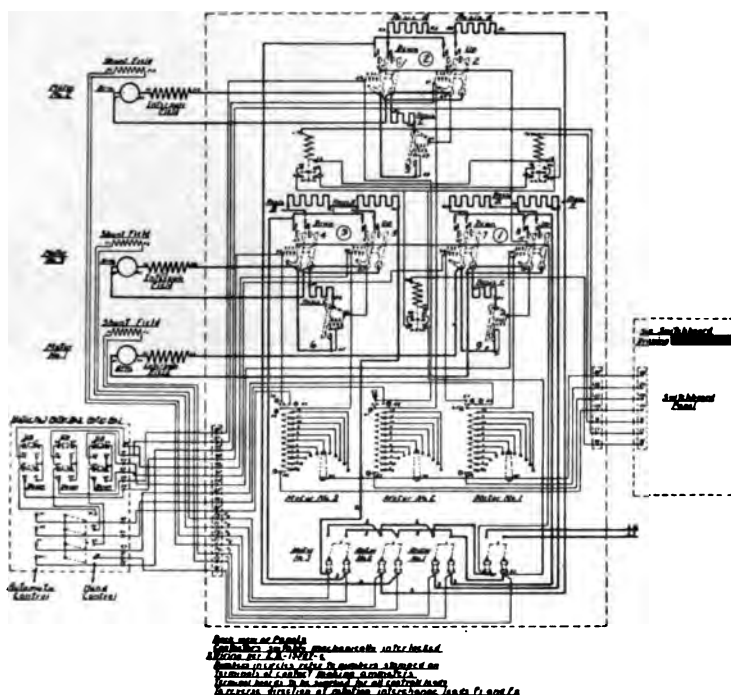


Fig. 6

which keeps the dirt and dust of the foundry off of the instruments and regulators.

Fig. 9, shows back view of furnace under construction. This view shows the electrode motors and winch mechanism and water pipe system.

Fig. 10, shows another back view, showing the water hose, etc.

Fig. 11, shows the Thury Regulator for electric furnaces. A small motor is required to operate this regulator

HEROULT ELECTRIC STEEL FURNACES

Size of Furnace Tons	K.W.	Ampere Each Phase	No. of 1/4" Copper Bars	Square In. Copper, Ea. Phase	No. of 1,000,000 c.m. Flex- ible cables Each Phase	Size of Electrodes	Ampere Square Inch Electrodes
1	375	2250	2 - 5"	2.75	4(750,000)	8	45
2	600	3600	4 - 5"	5.0	8(750,000)	12	32
3	750	4500	4 - 5"	6.0	8(1,000,000)	14	29
4	900	5400	4 - 7"	7.0	10(1,000,000)	14	35
6	1200	7200	6 - 6"	9.0	12(1,000,000)	17	32
10	2000	12000	8 - 8"	16.0	16(1,000,000)	20	36
15	3000	18000	10 - 9"	22.5	30(1,000,000)	24	40

Fig. 7

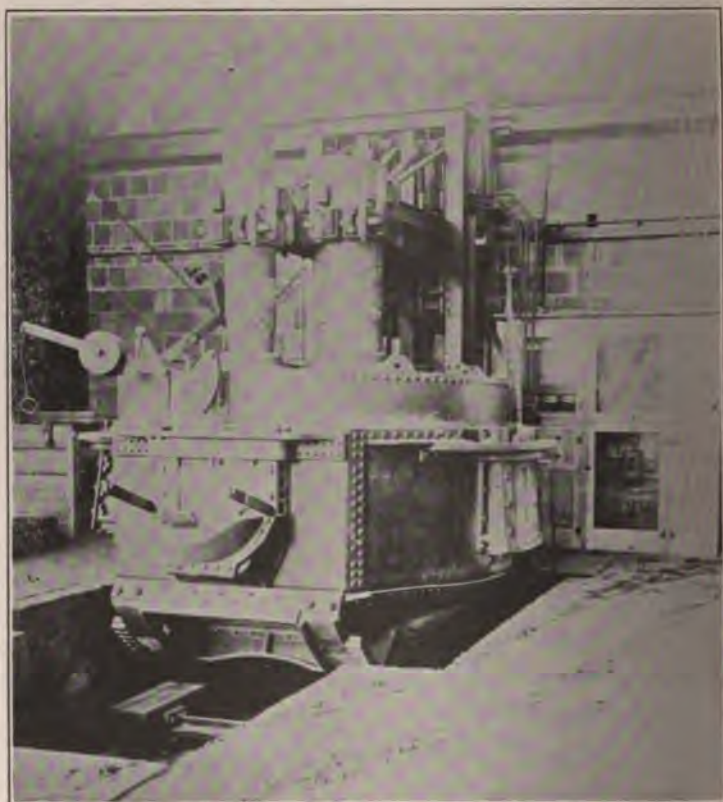


Fig. 8

either d-c. or a-c. motor being used. This regulator is a very good one but required both mechanical and electrical energy to operate. The small motor drives a countershaft which in turn drives the regulator. The motor is run con-

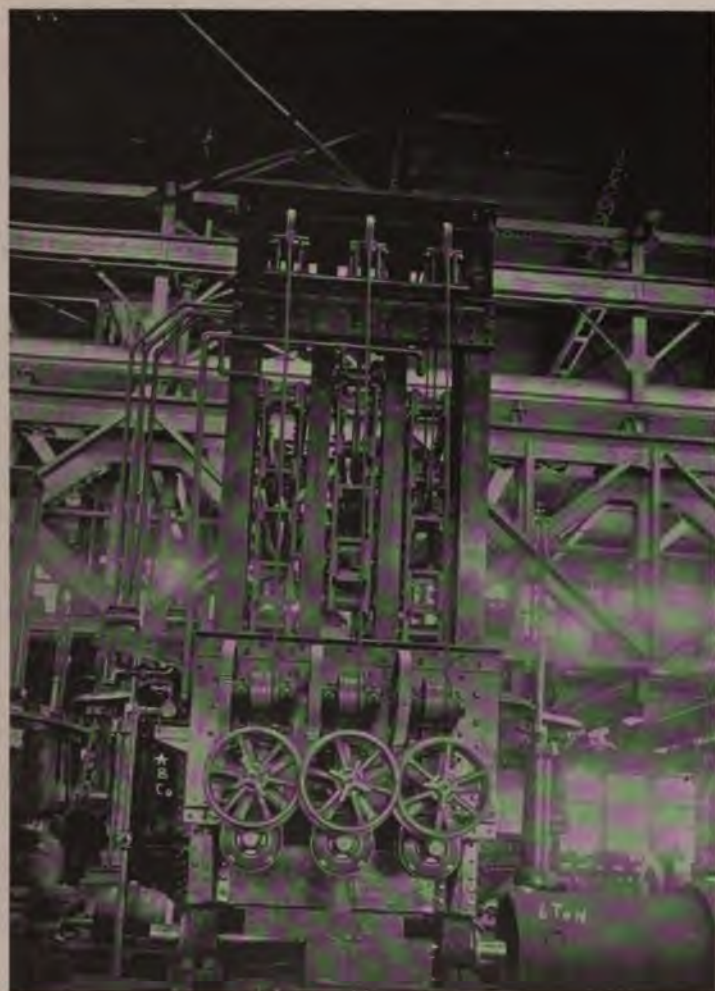


Fig. 9

stantly and the regulation is done by means of a tappet gear worked by a solenoid, which is actuated by the current. It is required to regulate. On the shaft of the tappet wheel

is fixed a lever carrying on its lower end two copper contact pieces. When at rest this lever hangs in a vertical position. Immediately the tappet begins to act, it sways to the right or the left against the carbon contact (which transmits the current to the electrode motors) and im-

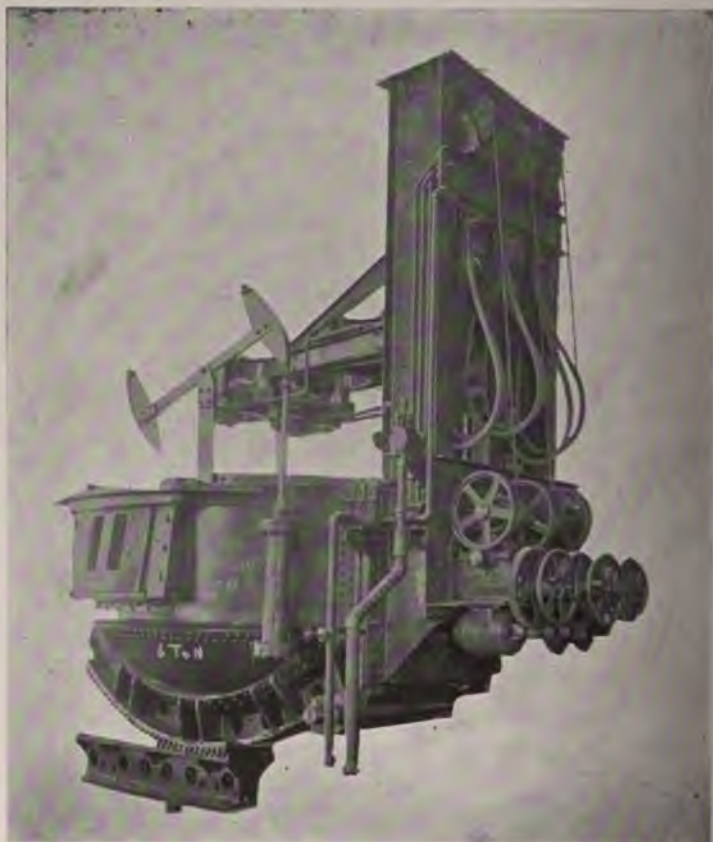


Fig. 10

mediately afterwards it returns to its middle position. When the winch is driven by a d-c. motor, the regulator is provided with a short-circuit switch at the bottom, so when the lever is at rest or in the center position the armatures of the electrode motors are under dynamic brake. This brake is released every time the lever swings to the right

or to the left. The regulator is provided with a damping arrangement to prevent overrunning or stops. When the regulator passes a current through the winch motor, the resulting variation in the furnace does not take place instantaneously, and if the regulator goes on working until the charge is made, it will have gotten beyond the proper regul-



Fig. 11

ating point, and will then start reversing with the result that periodic accelerations will be set up. The damping device which overcomes this tendency consists of a dash-pot which comes into action at each stroke of the regulator lever and opposes the continuance of the operation beyond

the required limit. It damps the action of the regulator. The viscosity of the oil in the dash-pot prevents the tappet working in the case of variations which are either too violent or of too short duration to allow of correction. The regulator is also arranged to use drum controllers and resistances to operate the furnace by hand. Also the advantage of these controllers is that the speed can be changed from one foot to three feet per minute, that is when the

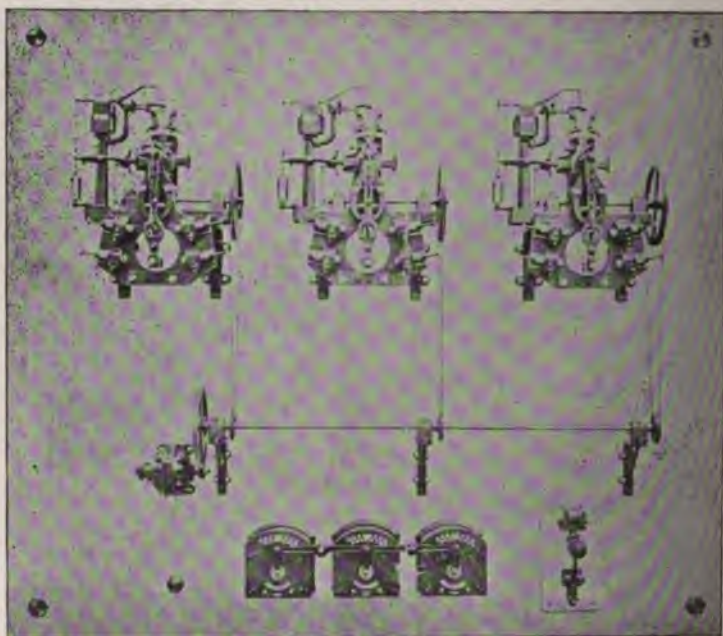


Fig. 12

heat is ready to pour, the electrodes could be run up at the high speed and save some time.

Fig. 12, shows the three Thury regulators driven by the motor and the resistance for regulating the current flowing to the furnace.

Fig. 13, shows wiring diagram of the Thury regulator for one electrode motor.

In the writer's opinion the ideal installation would be to have the transformers placed on pedestals as shown in Fig. 14, so as to use as short copper bars and cables as pos-

able, having the copper clear of all steel and iron parts. This picture shows bus-bars going through the mast, but in the new type, the bus-bars go over the mast, which is a bet-

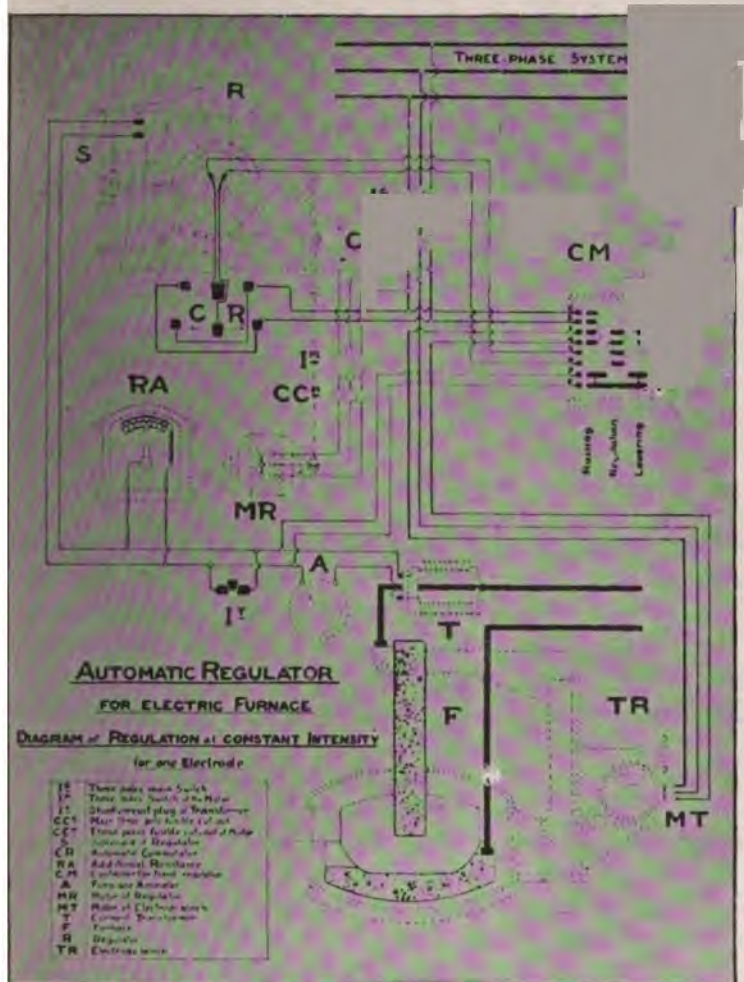


Fig. 13

or proposition from an electrical point of view. The small sketch shows the three transformers connected in delta, on the secondary side. There is a lot to learn about the electric furnace and the proper instruments to use, which will

develop as practice shows up the defects in both mechanical and electrical design and construction.

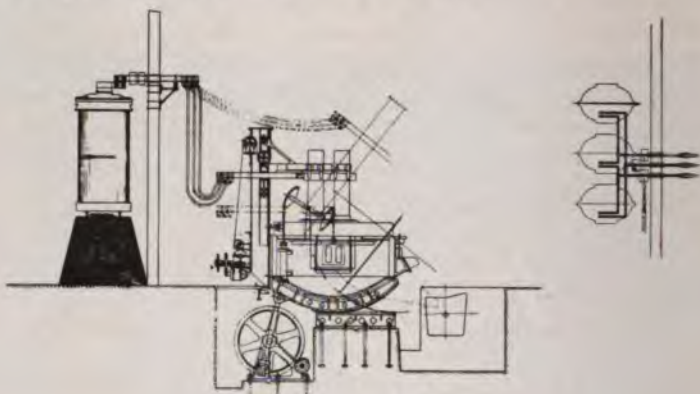


Fig. 14

DISCUSSION

A. T. Hinckley: One of the most important things in the use of large electrodes is the method of making the joints. In order to avoid loss of the butts the electrodes are threaded together, and the heating of this joint through contact resistance becomes a serious problem. The electrodes do not fit tightly together, and the joint surface, instead of being smooth, is made up of a number of point contacts. To overcome this, it is customary to use "dope" which is smeared on and the electrodes tightened up. The compound makes a smooth contact instead of a number of point contacts. The composition of such a compound has been the subject of considerable investigation by various companies making electrodes, and a few figures giving the actual resistance of these compounds may be of interest to electric furnace users.

These figures are made up on the basis of a current density in the electrode of 35 amperes per square inch. That seems to be what the designers of the Heroult furnace find most practicable and gives the lowest electrode consumption and the best furnace efficiency on the whole. The results are expressed in inches of length of electrode, the

resistance of such a length equalling the resistance of the joint.

If the electrode is screwed together, without any compound in the joint, the added resistance due to the joint is equivalent to between 20 to 23 inches of electrode.

One of the compounds which is very commonly used is made up of natural graphite, and it is mixed with molasses or perhaps glucose or some binding material of that kind, which, when it burns out, leaves a carbonaceous residue. That compound reduces the joint resistance from 20 to 23 down to 12 or 15 inches, but still the resistance is sufficiently high so that the joint heats up.

All of these compounds have a graphite-base material and the best compound we have ever found gave between 2 and 6 inches equivalent resistance in the joint. With such a compound the electrode will run at 25 to 40 amperes per square inch and the joint will run below red heat.

Another thing which is very important in making up electrode joints, is that the compound, and the amount used, must be such, that when the joint is screwed together, the layer of compound will be sufficiently thin so that it will not jar out when the electrode vibrates in the furnace. About one-eighth inch seems to be the best thickness for the layer of compound.

It is evident that if you have a thick layer of compound part of which jars out when the electrode is in use, a space is left. When the electrode is tilted at an angle due to the tilting of the furnace in pouring, the entire stress is thrown in the pin itself, instead of being taken up in thrust on the face of the upper section. As the electrodes themselves have a strength in tension of about 700 or 800 lbs. per sq. in., at an angle of 45 deg., the total stress may exceed the strength of the pin and cause breakage.

One point brought up at a previous meeting pertained to the strength of an electrode when heated, as compared with the strength when cold. Our work on this question is not complete at the present time, but we find in general, that the reduction in strength amounts to only 15 or 20 per cent.

Walter Greenwood: The very interesting paper under discussion is limited almost entirely to description of con-

struction and operation, and makes no contentions of superiority nor is comparison made with other designs. The paper contains a statement, attributed to Mr. James H. Gray, concerning the possibilities of electric furnaces in doing what cannot be done by older methods, which offers an opportunity for trying to bring out why it can do this.

While we are aware that the subject of the paper has been discussed before from the mechanical, electrical and metallurgical points of view it is just possible that some important consideration has not received the attention it should. Without full knowledge of what might be attained or of what we want to attain, it would be improper to claim superiority for any particular make of electric furnace. With such knowledge the full development and complete application of electric furnaces will sooner be brought about if they are destined to occupy any enlarged sphere of usefulness.

Attention is called to a few well known precepts with a view of building a foundation for the contentions and suggestions we are making. Good steel must contain nothing but fixed quantities of known elements, which are predetermined. There must be a perfect reconciliation of the elements toward each other, which will not exist unless there is a proper distribution. We have observed that the elements entering into different heats of steel may be exactly alike in every respect; the heats may have been made by the same process, in the same converter, by the same artisans, and while the heats may be alike in analysis they may be unlike in structure; some may be good and others bad. This must be accounted for in some way.

It is admitted that only three fundamental factors determine all steel-producing processes; chemical composition of the material, temperature and time. The first is predetermined. If the second can be controlled the third should automatically care for itself. The Bessemer process was not brought to its present state of perfection until a positive way of assembling the elements contained in the steel was thought of. By the Bessemer or open hearth processes of making steel, the elements required are predetermined but the temperature and time factors are not always under perfect control. Sometimes the temperature may, by chance

or design, be under perfect control but the time factor may not, in which case results are not always as desired. The only method for correcting such failure lies in heat treatment and it is an admitted fact there is no way of distinguishing between the material that needs heat treatment and that which does not. Although we may never arrive at that stage of development where heat treatment should be dispensed with, the correction it is required to make might be reduced to a very low point.

Experience and reasoning have led us to the conclusion that temperature is a factor that must be perfectly controlled to make good steel; that casting must be done with the temperature at or near the lowest point where the metal will flow. For many reasons, they cannot be given in detail here, this control is not uniformly maintained in the Bessemer or open hearth processes though it is more nearly possible to maintain it in the Bessemer. It seems as though the electric furnace could solve this problem of perfect temperature control and if the claims made for it are true, it has. The chemical composition predetermined, the temperature under absolute control, the time limit cared for and we have a near approach to positive methods from start to time for casting. The missing link in a positive process from start to finish is the matter of controlling temperature while casting large quantities of steel, where the time consumed in pouring is considerable and more or less variable. This is a problem that can be worked out. If no other method can be found the pouring can be done direct from the refining furnace.

Another statement attributed to Mr. Gray, concerning competition with coal or gas, will bear consideration. A matter that has not received the consideration it seems to deserve in the discussion of electric furnaces by this association is the cost of producing steel, especially where waste-fuel from blast furnaces is utilized. The limit set for this discussion prevents dealing with this cost question very fully but investigation leads us to think no one is justified in saying that electric current is too expensive to admit of competition with coal or gas for performing a part of the converting process in making steel. Among the items that should be considered are enhanced value of product, saving

through melting recarburizers with current, stoppage of waste through heats getting chilled and burning off stopper stems. Add to these some other charges that occur through wasteful practices that would not occur with a process that was ideally positive and possibly the ledger balance would be in favor of electric current.

Concerning enhanced values, we will illustrate in a single case. Most of the claims made for steel refined by the electric process are that the value is enhanced 10 per cent. or more. Assuming that this minimum estimated value 10 per cent is low enough, then in the case of steel rails selling at \$28.00 per ton we have \$2.80 to which should be added 10 per cent. of the cost of replacement. Of course we are assuming the life of rails to be 10 per cent. longer. The data at hand concerning cost of electric refining is sufficient to justify the belief that, with an equipment properly arranged for turning out large output, the increased cost of production would be considerably less than \$3.00 per ton even in the present stage of development of the process.

The foregoing remarks I have just made were submitted to a friend, whose opinions on matters pertaining to metallurgy I hold in high esteem, for approval or criticism and the following extracts from his statements are worthy of being introduced in this connection:

"Regarding your forecast for the future of the electric furnace, I believe you have restrained your enthusiasm even more than the situation required. The points that you mention—chemical analysis, temperature and time—are important, but only insofar as they influence the physical structure of the steel. I have always regarded this latter quality, physical structure, as a vital characteristic, and have valued the other considerations of analysis, temperature, etc., merely as a means to an end, the end being to secure the proper physical structure.

I have greatly regretted that we were unable to formulate a theory regarding the way in which physical structure might be determined by mill practice. After years of work, we have become fairly successful in securing the results aimed at, but we were unable to advance any explanation as to why we did certain things in a certain way; at least, any explanation other than the fact that they gave us the results we desired to attain.

You will remember that we made much good steel having a most absurd analysis, and at other times we succeeded in making with good material some steel which was bad. I am unable now, after all these

years thinking it over, to explain how or why, but certainly the point you mentioned of temperature control will prove most important and the electric furnace apparently secures a more perfect control than either the Bessemer or open-hearth, without exposure of the material to the action of gases of combustion, without a great absorption of gases by the metal resulting therefrom, which gases in their subsequent occlusion by the metal during the process of cooling are thought to be responsible for the occurrence of blowholes in the metal.

My own feeling, after reading your paper, is that you are understating the case of the electric furnace."

Frank H. Kittredge: I would like to ask Mr. Richardson what the best operating voltage is, according to his best experience, and also what style of electrode, graphite, or compound, is considered best.

Charles A. Menk: I might add that we had an electric furnace, probably under peculiar conditions, and it operated for about a year and a half. In the first place, the idea was to build a furnace to melt the stock by gas, and then refine it by the electric arc. You can see right there where we were going to run into difficulties. They wanted a furnace with a capacity of 20 tons, and there are very few 20-ton furnaces in operation.

You understand we have a few open hearth furnaces—something like sixty-four—and an electric furnace of 20-ton capacity among all those furnaces was like the tail-light on an automobile. The open hearth department really did not take any more stock in it than if it never had one, consequently the electric furnace was neglected a great deal, until finally it was decided to find out if there was anything in the electric furnace and then it was put under such management for test and for detail work, and finally it was decided to eliminate the electrical part of it, but still operate it as a gas furnace. As the furnace was located in the foundry, we found it very convenient for foundry work.

Another thing I might mention that probably helped to harm and discredit the electric furnace was the complications that existed in keeping the records and keeping the steel separate. That is all right in the case of a small steel plant so fixed that it can be done, but where, say, thousands of tons of other steel are made to one ton of electric furnace steel, it is quite an item to keep that sep-

arate, and we ran into difficulties right there; they thought we were making electric steel and selling it, when we were really furnishing open-hearth straight steel.

I have not any records at hand—I do not think they would be interesting even if I had—of the cost of repairs, but to anyone contemplating building a large electric furnace, I believe I could give some things beforehand. One refers to the electrical contact on top of electrodes. Certain conditions arise there that a mechanical engineer in designing, without really consulting with an electrical engineer, will slip up on, and that is the electrodes get hot, consequently the cap gets hot, and when it cools off the same contraction is not procured and nine times out of ten the moment the electrode cools off and the cap cools off, there is a loose connection.

Now, there is practically the same thing on the short end. That does not seem very much, but just so much that when starting up the second time, in place of having the arc in the furnace there is a hot top on the electrode, so there is one thing in a large furnace one would be up against. In a small furnace, probably in a 2 or 3-ton furnace, that trouble would not be experienced.

On a large furnace it is necessary to cool the opening for electrode, and put in a cooler around the top similar to that used in a blast furnace. It can easily be seen what happens there. On a large furnace a large electrode is used—we use them as high as 18 in. in diameter. That means the electrode cooler was several hundred pounds in weight. With a larger furnace it means that the top of the furnace had to carry the cooler. The moment the furnace became hot the top expanded, and when it cooled off it came down. Quite frequently the top of the furnace would fall in. These conditions do not occur in a small furnace.

I can speak of the large furnace more particularly, because I do not know anything about the small furnace. On the large furnace, with large electrodes, it was necessary to lift the electrodes clear out in order to clear the furnace. The moment the electrode was exposed to the air it started to scale off, and two or three feet looked like the end of a lead pencil. I do not know whether that works the same way in small furnaces as in large ones, but I believe in a

small furnace the electrodes are more confined and not exposed to the air while tapping. Also, quite frequently, when the electrode cools, the bottom part breaks off.

Another thing which I believe just as important as anything else about the electric furnace is the threading of the electrode. If you do not buy them threaded you must do that work yourself, and any one who never had any experience in threading electrodes will get plenty of it when he starts. We went at it very thoroughly, indeed, we worked with the National Carbon Company and several others, and had a great deal of hard work to get a good thread on an electrode.

I agree with all that has been said as to placing the transformer just as close to the furnace as possible, and be safe, cutting down the connections, and doing it just as simply as possible, because around an electric furnace complications are not desirable.

I might say that our furnace, working as an open-hearth furnace, is giving us ideal satisfaction, because I really believe it was designed and built by engineers that had been working on open hearth furnaces for years. They had that object in view, that the electrical end of it would be a simple detail, and that it would work out itself.

David B. Rushmore: There are two points which should be brought to your attention in connection with the electric furnace, the scope of which is so large that a discussion of the matter presented in the paper this morning is practically necessary. Electric furnaces are coming, and coming rapidly, and those familiar with the manufacture of steel are anticipating that a very large part of the steel in the future will be put through the electric furnace, because the gain in the quality of steel much more than out-balances the cost.

Like a great many other applications of machinery and of electricity, the successful outcome of these installations and operations is the result of care and detail, and the American Bridge Company and the United States Steel Corporation have both been handling this matter very wisely, with a great deal of care and study, and those who are thinking of installing and erecting furnaces would do very well, before they decide upon the exact location of furnaces, trans-

formers, busbars, etc., to consult the experience of those gentlemen, and also the experience that has been had in other places.

In the operation of the furnace, there are several items which come into play, and the principal one of these which has not been brought up this morning, but is a very important one, is that the success of every furnace installation is in keeping a practically constant voltage on the transformer. That is a factor in the power contract which should be taken care of, because no furnace, any more than an induction motor or any piece of apparatus designed to operate at constant voltage, will give satisfaction if there is a very great variation between the no-load or full-load at different times of the day on the high-tension or low-tension side of the transformer. It is suggested in lieu of anything else that this be limited at the present time and not to exceed a greater fluctuation than plus or minus 5 per cent. With a greater voltage than this it might be rather difficult to entirely control the conditions in the future.

The question of the cost of power which is under discussion has brought into very sharp outline the question of depreciation. As has already been said, engineers deny the validity of depreciation, stating that maintenance and repair should keep machinery up to date. Even if it is altogether rejected, it should be considered under the heading of obsolescence, but the lining of the roof of the furnace is a real depreciation, it is going to last a certain time under certain conditions, and that is one of the items in the cost of making steel in the electrical furnace, and there should also be considered in the same connection the wear on the electrodes. The higher the temperature at which the furnace is running, the shorter is going to be the life of the roof and the greater the expense involved and the more frequent the replacing. That is due to the fact that the electric furnace has no sharp limitation to output. You can increase the output of the electric furnace, or decrease it, through a considerable range of work, with a greater or less energy input, and at the present time there is necessarily—the high price of steel and the great demand for it accounts for this—a constant pressure to push this output of the

electrode and to work with the highest possible energy input.

All installations have, as a rule, been designed for certain energy inputs, and that brings us to the question of design of the installation, and also the desirable amount of reactance, both in the installation and in the step-down transformers, and the decision regarding the amount of reactance is, like most engineering questions, a question of compromise. It has its desirable features and its undesirable features. As far as the operation of the furnace is concerned, high reactance is desirable. Those of you who remember the operation of the old arc lamp will remember that it was absolutely inoperative without a certain amount of reactance to steady the arc. The fact that the current across the arc increases with a decrease in voltage, that is, as you increase the current across the electrodes, the voltage between the electrodes drops, makes the arc essentially unstable, so that if you have very low reactance between the generating apparatus and the furnace, in melting over cold scrap, you simply have an alternation between open-circuit and short-circuit, which makes very violent fluctuations, and as a rule, rather unsatisfactory conditions.

As this reactance is increased, the arc becomes more stable, and the operation of the furnace itself more satisfactory. The increase in reactance, whether in the transformer or in the installation, is a very great safeguard against interruptions and the disturbances that may come. A great many of these installations are in a place where the chain of a crane coming through easily short-circuits the transformer in dropping on the low-tension connections, and while that has not happened up to date it does not mean it is not one of the accidents to be guarded against.

A high reactance in the installation is desirable for operation of the furnace itself, it is desirable as a safeguard against internal destruction of the transformer by breaking down of the wiring of the apparatus, and it is also desirable as a protection against surges, or whether in unbalanced single-phase installations or more or less balanced three-phase installations, going back on the line, and to a greater or minor degree affecting conditions of the circuit

back of them. With proper insulation, this should be a negligible amount.

Reactance is undesirable from the standpoint of bringing a lower power-factor on the circuit or limiting the energy input to the furnace, and in that way limiting the output, the capacity of the steel you can get out in a given time, and also increasing the time of the heat.

Therefore the question of the reactance and the question of the voltage variation on the primary side of the furnace are two very important questions in connection with the very excellent design that has been shown here this morning for mounting the transformers from coils of the furnace itself, so that it is practically a unit, the transformer and the furnace really making a single piece of apparatus.

As Judge Olson said at the banquet last night, boys go wrong between fifteen and twenty-three years of age, and the electric furnace is probably at that age at present, and it necessarily has not attained yet its highest standard, and unquestionably a constant improvement will be made in all the principles in connection with it.

I think due to the care that has been used by all concerned in the cheap installations, it has in the introduction of this Heroult furnace, been wonderfully successful up to date, and I think all of you gentlemen are going to be very much involved in the use of electric furnaces in the future, and that you will all be very much interested in keeping in touch with the development of the furnace, and that you will make an effort to understand it as clearly as possible, and to comprehend the reasons for the installation of the different factors involved.

C. T. Henderson: I was rather interested to see that Mr. Richardson appears to have standardized on a bus-bar one-fourth in. thick, spaced one-fourth in. apart. I am rather curious to know why he has done that. My own experience, and I have had quite a bit with heavy bus-bars, is that it is preferable to use a thinner bar. A $\frac{1}{8}$ -in. bar is better than a $\frac{1}{4}$ -in. bar in my experience, particularly on alternating-current.

It is also my experience that it is a good plan to get the bus-bars spaced pretty well apart, so as to get the maxi-

im chimney effect and best possible cooling conditions. My experience is that the best results are had by using $\frac{1}{2}$ -in. bar, comparatively wide—say 6 inches—and I find it well to space the bars at least $\frac{3}{8}$ -in. apart. I have been wondering if Mr. Richardson's standards were simply adopted because he had to adopt a standard, or whether they are based on some particular experience he has had.

W. T. Snyder: It seems to me the time has come when this Association should have a Committee on the electric furnace, a committee made up similar to our Central Station Power Committee, with representatives of the electrical furnace people and steel-mill engineers on the Committee, to follow the development of the electric furnace, the trend of which is plainly evident by the large number of electric furnaces that have been built during the past year.

T. E. Tynes: I have a few questions I want to ask. Some have already been asked by other speakers. One of them is how much clearance they allow where the electrode passes down through the roof? Another is do they pull these carbons out when they pour, or are they left in? If they are left in, how do they take care of the weight of the carbon at an angle, and the other question is where the terminals are clamped on to the carbon, what means or method is used for fastening them on. The question of heating of the joint has already been taken care of in one of the questions of another speaker.

George W. Richardson: The object of bringing in this descriptive matter of the furnace, as contained in my paper, is for the purpose of bringing out the discussion that has already been had today. I will say, offhand, that the furnaces have been handed over to us to build, and that is all we know about the furnace. We do not have a furnace at our plant in operation, and we have no way of studying it. Once in a while we are likely to get out and see a furnace we are in the neighborhood. As I say, my experience of watching the operation of the furnace has been limited. I have not had, practically speaking, any experience on that point. The object of the paper was to bring out some points here that perhaps will help us along further on.

I think the questions asked by Mr. Kittredge has been answered by some of the other speakers. I could not tell

you just what the best carbon to use is. I have not gone into that. In reference to the carbon holder, about which Mr. Tynes asked, and also as to what is the size of the cooler, we allow about one-quarter inch all around for the carbon.

I would also say, in reference to the holder, we are not likely to have a great many hot spots due to contraction and expansion, but we found a little trouble on the first one we tried. We had a cable that ran there and connected to the holder, and our mechanical engineer had inserted an iron bolt, and the expansion was so great that it turned the V thread on the bolt, and every time we tried to open the hole we had a broken bolt. It also opened the contact, so that the cables would burn off six or eight inches from the holder. Then we put in a bus-bar and made the joint tight, and we have not experienced any more trouble.

The carbon holders, as we make them, are cast holders, and we insert good copper into the holders at that point so as to make the contact where they have to be opened, and where they have the joint, coming from the bus-bars to the tower is made of the same material, and we think we get a better contact there. That is the place where we take it apart. Other places are not so particular, as you do not have to take it apart. If anything happens to the holder, you can take the bolts out, and have good copper to go up against.

One of our customers, in the case of the first furnaces put in, had a considerable amount of trouble with his carbon holder, a small 1-ton furnace, the carbon holder was made of copper, almost in a solid condition, and just open enough to allow the carbon bushing through it to be clamped down, and it soon broke. They devised a hinged holder and made it of steel, made the holder of steel. Of course, for a 1-ton furnace they are doing very nicely with it. They have not had a replacement of the holders since they used that, and it is almost a year now since it was put in.

In my opinion, even for a large 6-ton, 15-ton, or any size furnace, I believe there should be a holder designed on something of that line, water-cooled, and it should be fully hinged, or clamped together in some way, so that when they do put it back or open it, there is no strain of the metal, it is just merely hinged, and it always goes back in the same

position again, and the holders will last much longer than they do today, and I believe you will find it necessary to have the holders water-cooled to keep them in that condition.

In regard to the size of the bus-bar that we made, I do not know that there is a particular reason why we should use $\frac{1}{4}$ -in. bus-bar, except that we had some of that size in our shop at the time, when we wanted to install the bus bars on the first furnace. We started in to use them, especially in making the delta connections from the transformers, and we continued using them, and that is about the whole thing. We did not want to go any heavier than that, although we were asked to go heavier, they wanted us to use $\frac{1}{2}$ -in. copper, but we objected to it, and we told them the thinner the copper the better the bars would be, especially the $\frac{1}{8}$ -in. copper bars would be much better.

Some time after that we were asked to go to 2,000,000 cir. mils or higher in all of our cables. I objected to that, an account of both the reactance and the flexibility of the cable. In my opinion, something on the order of Mr. Henderson's $\frac{1}{8}$ -in. copper bar, 6-in wide, will give better results, with a larger air space. We make the $\frac{1}{4}$ -in. air space more particularly because we wanted some space.

As I said, we brought up these subjects so that the discussion will benefit us in designing our furnace and the apparatus which goes with the furnace.

T. E. Tynes: In one of your pictures on the screen you show a big fulcrum near the spout. Did that leave enough room to get in a ladle which would take the capacity of the furnace? In the paper you show a lighter type of furnace with rolling trucks. Which is your practice now?

George W. Richardson: Our practice is to have the spout, with the fulcrum near the spout, and the foundations are cut away so that it allows the ladle to go under the spout. We think that type will give better results than the rolling type, unless we go away up in the 15-ton size, and that has not yet been decided, whether that will be of that rolling type or the lift type as I show in the small furnace.

In reference to the carbon or electrode joints, I know very little about it, but one of our customers came in to see me the other day, and he made mention of their trying

every kind of dope that was called to their attention to make good joints, and they tried to mix up a dope of their own from one of the other dopes that they got from some one, and they say they had it much thinner, and not so heavy as was furnished them. They claim they make almost a carbon joint, that is right down, and they had much better results by having the dope thin than by having it of too much consistency, as they have had it in the past, when they put it on the thread. I am only giving you what the gentlemen told me. He has a small furnace that has been working very hard, and he claims that he has obtained heat out of his 1-ton furnace in less than one hour and a quarter. We do not know what kind of steel, of course, is made, but this gentleman himself has said that he is making steel in an hour and a quarter, and making a ton of steel. I asked him what he used it for, and he said they had no bad results. I would like to say in reference to that particular furnace—a 1-ton furnace—the transformers were a little higher in capacity than what was recommended. He had three 150-kv-a., instead of three 125. I will also say that the reactance of the transformers is very small, the object of the people putting in the transformers was in case the furnace failed they could use it commercially on other lines.

The power house behind this little furnace is about two squares away. When he first started his furnace there is no doubt he had trouble in getting so much heat in the furnace. The side-walls and top were acting very badly. He has overcome that, through a little adjustment, especially on the motor, he had to adjust the electrodes and the dynamic resistance, so as to give a little more steadying effect and so as not to have the oil switch pull out so much, and since then he has made a test of everything that goes into the furnace—there is a slag-making material he puts in—and his claim is that it is the secret, to his mind, why his furnace melts so fast, and at the same time holds up both side-walls and roof. He claims it was the slag which allowed the current to penetrate down into the metal more than it did formerly in the case of some other slags, while other slags crept along the top and heated up the walls higher than he wanted them to be heated.

DESIGN OF STRUCTURES FOR STEEL WORKS

BY CHARLES A. RANDORF

The structures for a modern steel works are of many kinds, including buildings of various types, gantry cranes, unloading and re-loading bridges for handling ore, all of which cannot be adequately discussed in a single paper; therefore, the writer has selected for discussion what is considered as one of the most important structures, the Open Hearth Furnace building, which requires special care in design on account of the exceptionally heavy work performed in a building of this kind. Also the importance of space needs to be considered in the design.

It is the writer's purpose to bring out in this paper the fundamental principles to be observed and not to discuss to any length the technical side of the question.

The open hearth furnace building is divided into two bays or crane runways. The furnaces are placed near the center of the building to enable the overhead cranes in each runway to serve their respective sides.

The two divisions of the building are usually termed the "pouring" side and the "charging" side. On the charging side of the building, there is a floor at a proper elevation above the ground level to clear the checker chambers of the furnaces and to accommodate the charging machines and charging box cars. It is upon this floor that all of the materials to be charged into the furnaces are handled.

On the pouring side of the building the work consists chiefly of tapping from the furnace into the ladles, and pouring from the ladles into the ingot moulds. There is a continuous platform along the side of the building for the accommodation of the workmen, who attend to the pouring

of the hot metal into the moulds, and above this platform and supported upon the same columns, is a trestle with a solid steel floor covered with brick and carrying a narrow-gauge track for hauling the Spiegel ladle car. The elevating of the track above the general floor level saves valuable floor space.

In designing buildings of this character, the general plan of the plant is first laid out showing the arrangement of the furnace, checker chambers, flues and accessories. It



Fig. 1

is then the problem of the engineer to design the building to meet these conditions, which usually are not ideal in reference to the building.

There are two distinct types of open hearth furnaces now in use: the stationary type, and the tilting furnace.

In arranging the building, the stationary furnace will permit of a row of columns at regular intervals under each roof truss, through the center of the building. Some of the columns, therefore, must necessarily be placed adjacent to or in front of the furnace, a condition which is not permissible in connection with the tilting furnace.

The tilting open hearth furnace, on account of its movement and also for economy of space, will not permit close column spacing through the center of the building (Fig. 1). The purpose of the center row of columns is to support the two adjacent lines of crane girders, and in some designs these columns are utilized in supporting the center of the roof, thereby reducing the span of the roof trusses. However, the advisability of supporting a roof truss at three points is questionable, even though the theorem of three moments may be applied in determining the forces acting upon the truss.

There was recently designed and erected a building at the plant of the Lackawanna Steel Co., at Buffalo, in which the center row of columns is spaced 110 feet 0 in. between centers, which are at points between furnaces (Fig. 1) and the roof trusses span the entire width of the building, a distance of 124 feet 0 in. This building is particularly adapted to the tilting open hearth furnace. By having the roof truss span the entire width of the building avoided carrying practically 50% of the roof load on the center columns. This would mean either to use longitudinal trusses between the columns or support the roof trusses on the crane girders. This is not desirable as heavy vibrations would be transferred directly to the roof, due to the moving cranes below. Furthermore, by avoiding this condition, we believed that danger to the building was lessened inasmuch as occasionally the roof of a furnace will collapse, subjecting the steel framing directly above to an intense heat, and even though the crane runway girders were endangered, the roof would be comparatively safe. The crane runway girders are protected at points over the furnace by steel shields, which are suspended below the bottom chords. The roof trusses are braced in pairs or bents in the planes of the top and bottom chords. Also vertical bracing is used between top and bottom chords at points directly below the monitor posts and through the center of the building.

All of the above mentioned bracing consists of rods which are made adjustable by clevis nuts and turnbuckles, except in the plane of the bottom chords, which consists of angles rigidly connected to the trusses. The function of this bottom chord bracing, in addition to keeping the align-

ment of the roof and upper part of the building, is also to distribute any local force, such as created by the movement of the overhead cranes over a greater number of building columns. For this reason the bottom chord bracing was made continuous throughout the length of the building. The reason the heavier or fixed type of bracing was used in the bottom chords was on account of the difficulty erectors usually have in adjusting the rod bracing. In the fixed or angle bracing, the parts to be connected by the bracing must be pulled into their proper alignment and after the connection is made, no further adjustment is required.

The crane-runway girders of this building are of very heavy construction and are designed to carry cranes of 165

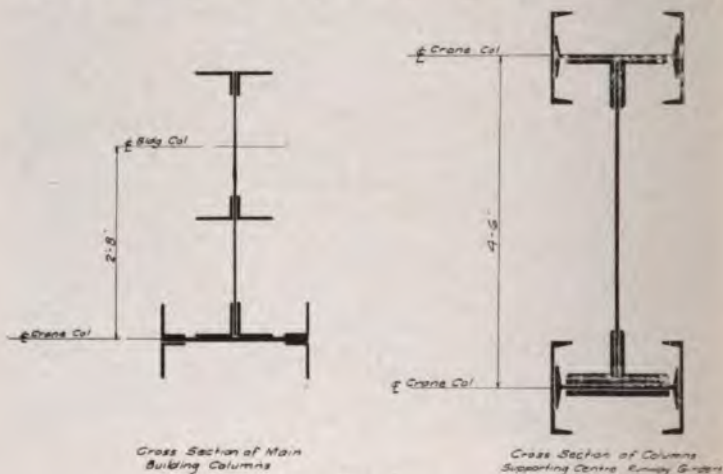
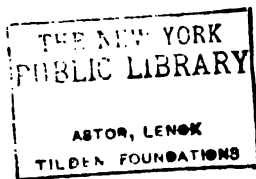


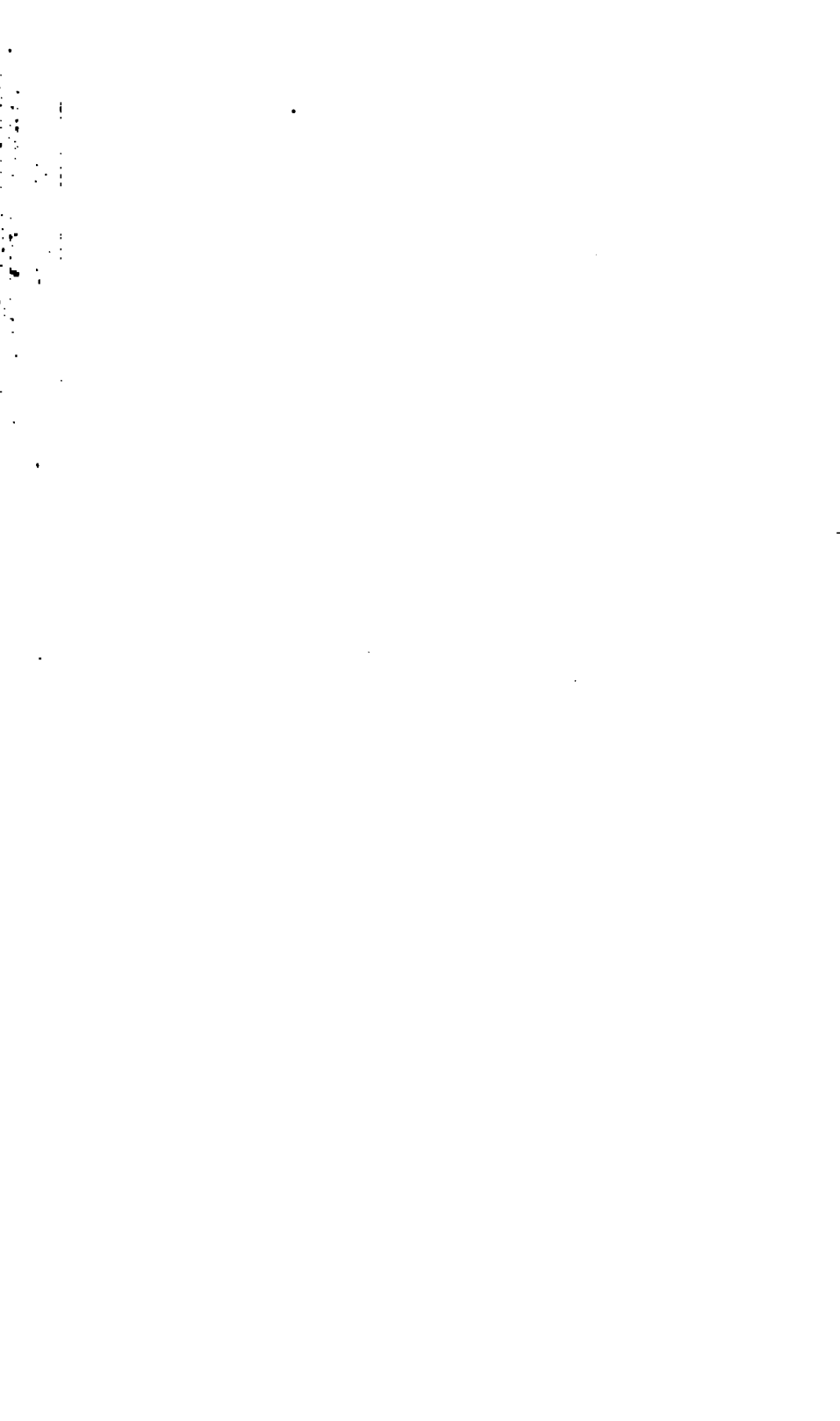
Fig. 2

tons capacity on the pouring side, and 75-ton capacity cranes on the charging side. The outer rows of girders have a span of 27-ft. 6-inches, and are of the box section type or double web, with angles and cover plates. The crane runway girders over the furnaces are of the latticed type, and are of exceptionally heavy construction, the span being 110-ft. 0-in. and weigh approximately 115 tons each. These two center lines of girders are well tied together with diagonal angle bracing in the planes of the top and bottom chords.

The rails used throughout on the runway girders are of the Cambria section weighing 150 lbs. per yard, and are



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fastened rigidly to the outer row of girders with cast iron clips, but the rails on the center runway girders are allowed to slide transversely by providing a clearance of one-half inch between base of rail and clip. This is to prevent binding of the wheel treads on the head of the rail, due to possible variation in the gage of the runway.

The columns supporting the roof trusses and crane-runway are of plate and angle construction, (Fig. 2) and are connected by extending the web of the building column to the web of the crane column which are at right angles. This makes a very rigid section and is necessary in large structures as the case at hand. The bending stress due to crane and wind load is considerable. The cranes are supported on girders 52-ft. $1\frac{1}{2}$ -in. above the base of the columns and the building is nearly 70-ft. 0-in. from base of columns to bottom chord of truss.

The actual amount of horizontal force produced on the building by an overhead crane in both the longitudinal and transverse direction is a problem rather difficult to solve, much depending upon the type of electrical control. The automatic control tends to more uniform acceleration, thereby reducing the shock and lessening the vibration. Also the skill and care of the crane operator are important, as the operator at times, under rush of work, spares neither crane nor building, therefore, it is necessary to be conservative in allowing for this factor in the design.

Some of the crane builders specify that a building or runway should withstand a horizontal force equal to 25% of the lifting capacity of the crane, but in the case of a crane handling a heavy ladle full of hot metal, the movement of the crane is very slow. The action of the crane when moving about light, seems to be the condition to consider. In designing this building, the total weight of the crane trolley acting in a transverse direction and the total weight of the crane acting in a longitudinal direction were used as a basis.

In the analysis of stresses for the complete bent of the building (Fig. 3) i. e. the roof truss and columns, the writer wishes to call attention to the anchorage at the base of the column, which is of considerable importance, as over 60% of the entire bending moment in the bent is resisted at the base of column at which point ample anchorage and bearing

area were provided. The bending moment, however, varies with the height and width of the building, and affects the amount of anchorage to be provided.

All crane runway girders and trusses in the building are provided with knee braces as usual in mill buildings. The knee braces under the large crane runway trusses through the center of the building are heavy channels with lattice-bar lacing. There was no opportunity for placing effective diagonal bracing below these heavy runway girders, and as several cranes were in operation before the building was completely erected, a longitudinal movement was noted in the entire center runway, due to the sudden stopping or



Fig. 4

starting of one or more cranes. This, however, was obviated by placing diagonal bracing in two panels at one end of the building (Fig. 4), at which point there is no furnace. The building has now been in use over three years, and the alignment of the runways is in an excellent condition.

The importance of providing ways and means for repairing the overhead cranes was duly considered. A plate girder of sufficient strength to handle the heaviest parts of the crane trolley was placed in the roof truss, about 6-ft. 0-in. above the bottom chord and about central with the runways.

These girders are provided near each end and at the center of each runway.

The floor on the charging side is designed for a load of 500 lbs. per sq. ft., exclusive of the weight of the floor, and wherever possible the main girders are placed at points below the rails carrying heavy wheel loads, such as the charging machine with a wheel load of 50,000 lbs., and also an 80,000-lb. ladle car, as well as a locomotive and four or five cars loaded with material. It is to be noted that the charging floor is connected with the yard level by means of an incline trestle, making it possible to haul all materials directly to the furnaces, including scrap iron, stone, and hot metal from the blast furnaces.

The floor plates are $\frac{1}{2}$ -in. thick, and supported by beams 2-ft. 6-in. centers. The floor near the furnaces is covered with a layer of brick, to protect the floor from being burned by the accidental spilling of hot metal.

In the writer's opinion the entire surface of a charging floor should be covered with brick, as accidents noted above frequently occur, other than in the vicinity of the furnaces.

Particular attention is called to the importance of utilizing space in a structure of this kind. The ideal knee brace as used in connection with the roof truss, should be 45° from the horizontal, but on account of the necessity of having a maximum travel for the crane trolley, the knee braces are as a rule flatter, thereby giving all the available space possible to the travel of the crane.

A platform for the convenience and safety of the crane operators is provided continuously along the side of the building. This platform is level with the floor of the crane operator's cage. This is to allow the operator to step directly from the cage to the platform at any point along the runway.

The ventilation feature of the building is rather simple, consisting of the usual louvre type of monitor so frequent on mill buildings. The dimensions of the monitor are greater than the average, the width being 41-feet, and the height 12-feet from base of monitor posts to bottom chord of monitor truss.

Steel shutters are used on the sides of the buildings instead of glass windows owing to difficulty of keeping the

glass in repair and clean enough to properly light the building. The shutters have proven entirely satisfactory, both from a lighting and ventilating standpoint.

BASIS OF DESIGN

The wind load was assumed at 30 lbs. per sq. ft. on the sides of the building and 15 lbs. per sq. ft. on the vertical projection of the roof. In addition to the above wind load, the roof is designed for a quiescent load of 30 lbs. per sq. ft., 10 lbs. of which is for the roof steel and roofing and 20 lbs. for snow. Other forces affect the roof truss, such as the action of the knee brace. This is clearly demonstrated by the accompanying stress diagram (Fig. 3). It will be noted that the maximum bending moment in the bent occurs at the base of the windward column, and as before noted, the crane and building columns are rigidly connected and of sufficient cross-section to resist the bending stress in addition to the direct stress. In determining the unit fibre stress, the formula

$$f_1 + f_2 = \frac{Mn}{I - \frac{Pl^2}{10E}} + \frac{P}{A} \text{ was used in which}$$

f_1 = Stress due to bending.

f_2 = Stress due to direct load.

P = Direct load.

l = length of columns in inches.

n = Distance from neutral axis to extreme fibre.

E = Modulus of elasticity (29,000,000)

A = Area of cross-section.

I = Moment of inertia of section.

For further information regarding the above formula see "Modern Framed Structures" by Johnson Bryan & Turneaure.

For all columns with simple or direct loading the formula $P = 16000 - 70 \frac{l}{r}$ was used.

Referring again to the base of the main building column, seats are provided for the anchor bolt which extends about 18-in. above the foundations.

The connection between the seat and column is designed to develop the strength of the anchor bolts, and the ten-

sional strength of the bolts on one side and the bearing strength of the concrete below the base of the column on the other are intended to produce a force couple to resist the opposite forces due to the maximum bending moment at the base of the column.

The roof is covered with No. 18 gage corrugated steel, and the sides with No. 20 gage of the same material. On the west side of the O. H. building there is a lean-to on which is used No. 14 gage corrugated steel on account of the necessity of providing for the dropping of ice from the eaves above. All of the corrugated steel is fastened to the structures by means of spiking pieces bolted to the purlins

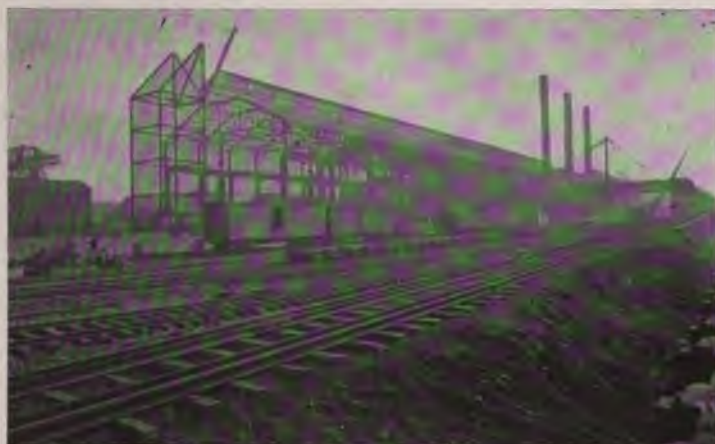


Fig. 5

and girts, and the corrugated sheets are nailed to the wood spiking piece. This has been tried out for a number of years, and found to be satisfactory, both in the point of erection and in making repairs.

In erecting the building, all material had been delivered to the building site, except the heavy crane runway trusses. A steel traveller (Fig. 5) provided with two 65-ft. booms was used. The booms were designed for capacity of 15 tons each. The radius of the traveller covered the entire width of the building, and the erection of the building was completed as the traveller moved along. All materials were

handled by the traveller except the heavy center runway trusses, in which case heavy jin poles were used.

The girders were pulled in place by two hoisting engines. These girders are probably the heaviest of their kind, and special care was observed in handling and erecting them. Also the columns supporting the same are of sufficient width to afford a firm seat for connecting the girders. The web of the column extending between the girders and the ends of the girders are riveted together through the web plate. No expansion was provided throughout the length of the runways.

The building is 126 feet wide and 1038-ft. long.

DISCUSSION

W. T. Snyder: We regret very much that we have to ask the author of a paper like this to cut his time so short, because we realize it takes a lot of work to get up a paper of this sort, and we also appreciate that this subject is an interesting subject to the steel mill engineers. I suggest there are certain points which might be brought up in the discussion, and if we do not cover it here any members who contribute to the discussion later might touch these points. This discussion could take up some of the things we are continually running into in the design of steel mill buildings, the foundation and bracing of the building, and the effect of this on the apparatus in the building; methods of getting to the crane and power system; illumination systems, wiring, etc., also the matter of clearances for cranes. If we can incorporate these matters in the discussion of this paper, it would be valuable material for our proceedings.

There is a great deal to be said, and while it may be out of order, I might suggest to the Paper's Committee for future years that one paper would be enough for one session. This is such an interesting subject that we could discuss it for three hours, if we had the time, but we have a little less than one hour in which to discuss all the valuable points in the paper.

S. C. Coey: There is one question I would like to ask Mr. Randorf. I notice he states that no expansion was provided for in the length of this runway and that the length was 1038 feet. I would like to know if the building is in operation now, and whether they have experienced any trouble due to expansion in that length. It would seem to me that on a runway of that length there should be at least two or three expansion joints provided in the open-hearth building, such as described here.

C. A. Randorf: We have two open hearth plants. Open hearth plant No. 1 was erected about 10 years ago. We provided for expansion in the furnace building of this plant, and have since found a considerable movement and vibration in the structure due to the traveling cranes.

In designing our open hearth No. 2 structure, no provision was made for expansion. We believed that having the entire building act as a unit in resisting external forces would be an improvement.

S. C. Coey: Is the building in operation?

C. A. Randorf: Yes, it has been in use for three years.

S. C. Coey: No trouble?

C. A. Randorf: No. It is in an excellent condition. We did allow for expansion in the bottom chords of the heavy crane-runway girders. To avoid secondary stresses, slotted hole connections were provided at one end of each girder.

Robert J. Young: We have all appreciated the splendid paper prepared by Mr. Randorf, and it is especially gratifying to the Safety Engineer to see the care that is being taken in the designing and laying out of modern mill buildings, as the tendency now is to provide ample strength in the structure to withstand the vibrations due to the operation of heavy machinery, and ample space in which to do the work safely.

The platform provided along the side of the building under discussion, for the safety of the cranemen, has proved itself to be a very important safety feature. We have found it important to add to this precaution, means for the escape of the men working on the pouring platforms, especially where the platforms are quite high and long. This protection consists of one or more lean-tos along the back

of the pouring platform in the center of which is placed a fireman's pole. If there is the necessity of a quick escape, the men can jump through the opening in the wall of the building and slide down the pole to safety.

We also believe it important that furnaces and pits be designed for removable receptacles in which scrap, kish, etc., may flow or be dumped, and that a sufficient number of these receptacles be provided so that slag may become solid before dumping. The old practice of running slag in comparatively deep pits or dumping it on the ground from ladles in the mixer building has proven to be very costly.

Several serious accidents recently have called attention to the necessity of providing resting places for workmen in open hearth plants. Because of the nature of the work, a number of the men have rest periods, and unless a safe place is provided for them to rest a dangerous location may be chosen for that purpose. Not long ago, a man was found asphyxiated back of an open hearth furnace. This man had placed a bench near the back of the furnace upon which to lie. When he was found lying there later, he was dead. A post mortem examination showed that he died from carbon monoxide poisoning. The bench was in a comparatively clear space back of the furnace, and there was a good breeze blowing away from the man and towards the furnace. Another case brought to our attention was where a door boy having a rest period placed a bench near the charging car track and lay down to rest. The bench cleared the cars on the track, when the boxes were properly placed on the cars, but a car was shoved by with one of the boxes extending considerably over one side and it caught the boy, seriously injuring his spine.

Another fatality was brought to my attention recently, where a man, during a spell period, lay down near some empty moulds in an open hearth pit, and these moulds were struck by a mould carried by a crane causing one of them to fall on the man, killing him.

It is customary now, when designing a building, to provide toilet and washing facilities within the building, and in making this provision it is easy to go a step further and provide rest rooms where the men may rest in safety and comfort, and at the same time the foreman will know where

he can find them when needed. In laying out such an installation in an open hearth building, we have found it convenient to place two or more long narrow buildings on the charging floor and a couple of similar buildings on the pit side just outside of the building proper. These buildings contain lockers, toilets, wash rooms, showers and benches. Buildings on the outside are provided with what might be called sun porches, i. e., the rest rooms are on the ends of the buildings and are so constructed that they may be enclosed with glass in the winter.

There is no argument now against the advisability of providing pleasant and comfortable surroundings where men work, and it has been proven that such provisions are valuable both from a safety and an operating standpoint.

A. G. Place: I ask Mr. Randorf if there is much movement noticed on the center runway where the rail clips are spaced half inch clearance, and whether this movement is noticed when the seasons change, as spring and fall.

W. T. Snyder: It has been our experience that the rail clamp with a single bolt to hold it is hard to keep tight. In the design of new buildings that is an important point, the crane rail should be held down with a clamp having two bolts.

T. E. Tynes: I do not think that we electrical engineers always appreciate the difficulties that the structural engineer is compelled to face in the design of buildings in which to house and utilize our equipment. The practice of his profession may tell him what is the best place to put a certain column for economy of material or to take care of stresses, but owing to the fact that a tilting furnace or a standard open hearth furnace, has to go there, he is not allowed to place the column there, and consequently he must take care of the additional space where the column is removed by increasing the trusses involving heavier construction, and that is the condition which was met with in this plant.

At the bottom of the fourth page of the paper, reference is made to the fact of the span being 110-ft. O-in. and weight approximately 115 tons each. I think that is probably one of the heaviest spans of this nature that has ever been constructed in an open hearth building and great care

had to be exercised in the handling and putting up of this truss.

John C. Reed: In looking over the diagrams and views shown in the paper, it strikes me that the views of the open hearth are very familiar, and it does not seem to me that there has been any improvement in open hearth building construction in the last ten or twelve years—the same designs have been followed. There is one difficulty which we have always had in open hearth work on the pit side of the furnace in getting some means for using lighter cranes for doing the lighter work. We have gradually gone up from 50-ton pit cranes to 75-ton, 100-ton, 150-ton, to 200-ton, and we are talking about a 250-ton crane, and when it comes to using such heavy cranes for doing what I would term the "hobo" work on the pit side, it does not seem reasonable.

Last summer I had a great deal of trouble with a large pit crane, the bearings getting hot, due to the great amount of bridge work which this crane had to do, yet there did not seem to be any way to get away from it, and one day I went into the open hearth and saw the pit crane carrying a stopper rod down the mill, and I tackled the open hearth superintendent about it, telling him I did not see why we should use a big crane to carry a rod which one man should be able to carry. He said: "You cannot get men to carry things nowadays. When I first ran an open hearth furnace, if a man could not pick up a 200-lb. piece and throw it into the furnace, we would not have him on the job." The facts are, you cannot get men today to lift any kind of a load at all.

For a number of years we have used in our bridge shop and steel foundry a type of crane known as a wall crane, also termed a traveling pit crane, which operates on a vertical runway along the side of the building. Such a type of crane, if installed on the pit side of the open hearth, would be a great improvement, and we have considered the installation of such cranes. The trouble, however, is that the present open hearth structure is not suitable for it, has not been designed to carry such crane, and another difficulty is the fact that such a crane will foul the position of the cage on the pit crane. There is a question in my mind whether the position of the cage at the end of the crane is absolutely

necessary. It used to be necessary to keep the men down low, with the ladle, so that they could see what they were doing when pouring. That is not so necessary today, as I believe the practice today is to use pouring boxes and the man on the crane does not have to spot the mold so accurately as previously. I believe the cage could be put out in the middle of the crane, and wall cranes used on both sides of the pits, so that they could not only do the light work over the moulds but also the light work for the furnaces themselves and save the bridge movement in many cases.

C. A. Menk: We have not erected many new buildings in the past few years. We pay particular attention to safety. We believe in designing buildings that there is one important feature which should be taken into consideration, and that is the feasibility of making arrangements so that the men can go up on the crane runways to make repairs to the crane.

We have erected one building in the last eighteen months, in which provision was made for all repair work to cranes by putting foot-walks along the girders in between the columns on the sheet-iron side. In the mill they put in plates between the girders and between the charging floor of the main building, and we see the great improvement in having these provisions arranged on new buildings. It makes it convenient for the crane men and repair men in going to their duties.

Another thing which I believe should be done in designing buildings is to take care of heavy repairs. Some years ago we made provision in the open hearth building for 15-ton runways over ladle cranes. I am safe in saying that the erection of the crane almost paid for the additional structure.

I think that is a very important piece of work. I think where you have large cranes, up as high as 175-ton ladle cranes, these parts of the cranes are all massive, and heavy. It is important, therefore, that the other structures should be built to take care of these parts.

I think it is very important to know what you have to handle when you are designing the building, more particularly a building for open hearth furnaces than any other

part of the mill, because in the open hearth building a great deal depends on how easily you can do your repair work.

W. T. Snyder: Another feature in connection with the design of a building that has electric cranes running inside, is the matter of keeping the weather off the rail. The rail gets wet, and the trouble and expense it causes on the crane sometimes justifies the cost of a watershed.

You have a different condition in a mill building, which is supposed to be enclosed, but the building may be so located that there may be an occasional rain-storm which would put water on the rail, and at the same time particles of dust may collect on the rail, making it slippery. This condition would not exist on out-of-door runways, where the rail would always be washed clean.

W. Frank Detwiler: I have been building quite a large amount of outside work, and I wonder if putting footwalks on the entire length of the craneways is good practice, for the repair men to get out on the tracks.

J. H. Wilson: A matter that I think is well worthy of consideration has come to my mind during the discussion. That is the question of making provision in the original building design for wiring, pipe-lines, and similar equipment.

In the East Side plant of the American Rolling Mill Company, all necessary dead-ends, cross-arms, supports, etc., required for wiring installation were taken care of in the original building construction, making it unnecessary to drill field holes or to put up brackets after the building work had been completed. It is at times necessary to install steam-lines and water-lines overhead, and they could be taken care of in a similar manner.

Best modern practice installs steam, air, water and hydraulic lines in a concrete ditch covered with iron plates. This could not always be done as special conditions frequently arise which require overhead lines. Considerable of the cost of the ditches could be eliminated if they could be put in at the same time the foundations are installed.

In one case, a walk which had been put the full length of the outside runway to facilitate crane repairs, had to be cut out to make room for a steam-line because provisions

for such steam-lines were not made in the original structure.

A little advance thought given to making provisions in the original plans for necessary wiring, pipe-lines, etc., will result in considerable saving both in cost of installation and in conflicts which arise between the location in a mill of the different types of installation. For example, underground electric conduits have to be run in such a way as to avoid pipes already installed, or a pipe-line has to accommodate an electric conduit, resulting in extreme expense in one case or the other. More complete plans covering both electrical and mechanical installations would eliminate beforehand such conflicts, and result in more satisfactory construction.

W. T. Snyder: The point that Mr. Wilson makes is more important today than it was a few years ago. There was a time when to put a steam-line or an electric-line anywhere on the girders, meant that men worked out on the crane, when there was time, then let the crane work awhile, and get the work done in that way. That is not now tolerated in steel mills. When men work overhead they must have safe and secure scaffolding and the crane must stop operating while the work is going on. It is now more expensive to take care of these after-considerations than it was a few years back.

Alfred F. Hovey: I received a letter from the President asking me to look over this paper and bring out one point, which has already been very well covered by Mr. Wilson.

The paper as presented is very valuable for engineers planning their buildings and equipment, and I have nothing to say about the paper itself except to add that the electrical requirements for the mill building should be considered extremely important, because of the economy in cost and convenience in laying out this work. We know, of course, the mill owners have changed their attitude in regard to the use of electric power, and now give adequate space to the detailed requirements for this apparatus in the proposed layout of new buildings.

It has been altogether too common a tendency, as has been pointed out, in designing buildings to design them with-

out due consideration for the electrical requirements. A few consultations with the electrical engineer at the time the design is made up will often result in a vast economy, and will avoid those unpleasant complications when the electrical engineer is asked to do certain things in a building, where no space has been provided for this equipment.

It is unnecessary to put before you the facts which have led up to the adoption of electric power, except to mention economy in operation, and you as representatives of steel companies, having this work in charge, should also have these things in mind for the safety of employees, as one of the elementary factors in the design.

The individual power station, or the central station where electric power is generated or purchased and distributed to various mills and other requirements, has largely done away with the various boiler and engine rooms. In making these designs in conjunction with the electrical engineer, it will result in a great deal of economy if the distribution of power is taken into consideration so that the buildings can be so grouped, that plans for conduits, trenches or troughs can be provided for the use of underground cables. Then there may be adequate provision, instead of the electrical engineer receiving the order to install motors for cranes or hoists together with conductors for the power in some particular place where no space has been allotted by the architect in his original design and no thought of the necessity of supplying power for such installations. Work along these lines can be done at a greatly decreased cost and at a considerable saving over the expense as compared with this work when done after the building is laid out and constructed.

Another important matter, which is well to keep in mind at the time of making the design for the buildings, is the foundations for motors. These are often overlooked, and that means floor plates have to be cut or floors torn up in some cases, and in plants with which I have been familiar within the last year, where electrical power has been installed in steel plants, we have had to interrupt the operation of the machinery, or do the work at night at increased cost. Even that method does not make much difference, because so many of the plants are working night and day,

but it means an interruption in the production. The maximum output cannot be obtained while such work is in progress.

We can not emphasize too strongly the necessity of exercising the greatest care in the matter of clearances, and particularly the provision of adequate space for suitable terminals at the ends of cables to prevent electrical leakage.

This matter was well covered in Mr. Egan's paper last year at the Convention, and if improvements that are often considered of secondary importance to the designing engineer are advocated by the electrical engineer, very often these clearances can be provided at the time the buildings are originally laid out, so that there will be enough room for necessary auxiliaries and we can keep in mind the safety of employees. The underground electrical systems have proved to be of great advantage where adopted, and that brings up the question of conduits so that they can be placed under machines or other equipment that are to be connected with the conduit lines, without interrupting the production.

My main point is that if the electrical engineer is only given a chance, or takes the opportunity of talking these things over with the architect, that considerable expense can be saved rather than by making changes or additions at a later time.

C. A. Randorf: One of the gentlemen asked if any movement was noted in the loose rail which is mentioned in this paper. We have no trouble in this respect. We have had some trouble with single bolt rail clips which were used in some of our older structures, but we now use the two bolt clips in all cases, and with the loose rail clip on one side of runway, we find the same satisfactory.

Mr. Detwiler has suggested that provisions be made for footwalks on all crane runways; also means to get on roof of building. We have made provisions of this kind on some of our buildings, especially walks along runways for the use of mechanics and electricians also foot-walks on buildings for taking care of windows. The footwalks on crane runways are very important, and we believe in using them wherever practicable.

W. Frank Detwiler: Outside runways?

C. A. Randorf: Yes, we have used the same on outside runways, with ladders at different points for convenience. We have elaborated on this scheme and used stairways and I believe these most satisfactory.

We also have provided foot-walks in the roof trusses of our mill buildings, directly under the main power lines for the convenience of the electrical repairmen. Access to this particular foot-walk is obtained by means of ladders at each end of the building.

PORTABLE ELECTRIC TOOLS AS APPLIED TO THE IRON AND STEEL INDUSTRY

By A. M. ANDRESEN

Portable Electric Tools, as referred to in this paper, will be Electrically Operated Drills, Reamers and Grinders. Before going into the application of these types of electric tools, I will endeavor to give you a brief outline of Electric Tools and their development.

The first tool; namely, the Portable Electric Drill, was commercially used in this country about 1902. Small-size drills, of direct current type with drilling capacities up to $\frac{1}{2}$ -in. in metal, were first introduced.

For a number of years, the Electric Drill was used only on miscellaneous repair work, etc., in a few plants. Some trouble was experienced, which later developments proved to be weakness in design. There was also considerable skepticism as to its successful application in general. However, the advantage of the flexibility in the application of the Electric Drill was recognized by some users, with the result that they co-operated with the Electric Drill Manufacturers; and fairly rapid progress was made in its development to better meet the varied conditions existing in these plants.

In the early type of Electric Drills, the shunt wound motor was used. Considerable trouble was experienced with this type of motor, and series wound motors were then used with good results.

Considerable comment has been made on the use of series wound motors in Portable Electric Drills; but when the Portable Tool Manufacturers were put to the question of which would be the best type of motor to adopt for these machines, the thing most apparent was the fact that these

motors were to be operated under extreme heavy duty conditions and subject to sudden strains of heavy loads; and it was found that the type of motor, as used in street cars, was preferable.

For still heavier classes of work, it was apparent that in steel mills practically the same type of motor was employed; and in numerous other places, this type of motor was the most prominent in use for heavy duty practice of this kind. The series type motor also has, for its advantage, the extreme simplicity of motor design, which can be found in no other type of motor, with the exception of the squirrel cage induction type motor.

It is readily apparent to those familiar with motors that there never has been a motor made which will accelerate under heavy torque loads equal to the series type motors. It is also acknowledged that no other type of motor can be made to withstand the punishment that the series type of motor can withstand.

When considering a quantity installation of this type of machine and the effect of operation where they are thrown in and out of circuit, one can readily appreciate the impossibilities of making proper consideration for these peak loads, which greatly affect current conditions flowing on the line. Naturally, the design of the series type motor is such that, a machine being thrown in the circuit under these conditions, the peak is considerably less in proportion to the load than it would be if shunt or compound type of motors were used; and it is only necessary to consider an installation of a fair sized proportion to appreciate the operating conditions which this line must withstand. Therefore, it certainly is advisable to eliminate these peaks as much as possible.

Another point of consideration in this extent, as taken from the shunt wound type of motor, is the fact that these machines, thrown on to the line directly—as they must be in order to operate under their conditions—only the armature would be across the circuit. And when a machine of the larger size; i. e., approximately 3 to 4 h.p. is thrown across the line in this manner, without any starting resistance to relieve the rush of current, it is readily appreciated that multiplicity of same will give a short circuit to line conditons.

During the development of the Portable Electric Drill,

the question of properly ventilating or cooling was carefully considered. In the early types of Portable Drills, the method of ventilating was very poor. The type of fan used in the early type of drills was made on the principle of an air cooling fan, such as is employed in rooms for direct ventilation. Considerable experimenting was done with this type of fan with practically no success.

The next experiment was along the lines of an exhaust fan. This proved far more satisfactory than previous methods. When this method of ventilating was first put in use, the intake of air was drawn directly through holes in the top head, or commutator end of the machine, passing over the commutator down to the armature and fields, and exhausting through holes in the bottom of the motor housing.

It was later discovered that, when machines were operating in plants where considerable dust and dirt was in circulation, same would be drawn through this direct course and would accumulate on the commutator, brushes and brush holders; and in some cases, cause considerable trouble due to this foreign matter short-circuiting the brush arrangement and also the commutator. To eliminate this trouble, provision was made for the intake of air below the commutator and brushes, thus leaving the brush arrangement entirely housed, with no opening; and consequently, no dirt or foreign matter could get to the commutator and brushes. This arrangement is generally used in present day machines, and has proven satisfactory for all sizes of machines.

The method of lubrication was also given careful consideration along with the developments of the Electric Drills. The gear case, which contains what might be termed the mechanical parts of the Electric Drill, is partially filled with a good grade of grease or non-fluid oil. Some trouble was experienced in the early type of drills to keep this grease from working out of the gear case. Indications were that the centrifugal force of the fan would practically expel the grease from the gear case, working its way into the motor housing and clogging the outlet of the ventilating fan, causing the air to churn in the motor housing, which naturally would interfere with the ventilation of the motor. To overcome this, became a matter of development. An improvement in this direction was recently made by providing small

vent holes in the gear case, directly below the fan, which provided an eddy current of air to counteract the suction caused by the fan. It is, of course, essential that a good grade of lubricant be used—one that will hold its consistency under different temperatures.

During the development of the Portable Electric Drill, considerable trouble was experienced with the switch. Numerous types and styles of switches were used, such as the sliding contact switch, the butt contact switch, the magnetic switch, etc.

It was soon discovered that, owing to the condition under which these drills must break the current, generally a heavy arc would follow, which in many cases, would cause a complete burning out of the switch mechanism. It was then decided that a more adaptable plan would be to follow the principle as employed on a circuit breaker, allowing liberal factors of safety for the breaking distance of this arc.

In the development of this type of switch, same was arranged wholly along the lines of the breaker; and it was soon discovered that the operator, in closing the contact of the switch, would not force same in properly. This would allow only a partial contact to be made, causing a high burning arc, which in many cases would completely melt the contacts. It, therefore, became necessary to make both operations of the switch remote in their control, to the effect that when the operator threw in the switch, the movement would be such that it would release a member and make an automatically quick, positive-closed contact, the same operation to be used in relieving or opening contact of switch. This principle has proven quite satisfactory, and is, at the present time, generally employed on all classes of drills.

The development of the larger sizes of Electric Tools afforded an opportunity of entering into broader fields in their use, such as heavy drilling, reaming, etc., which, up to this time, had never been contemplated with the Portable Electric Drill and which, heretofore, had been done with the hand ratchet or pneumatically operated portable drill.

Inasmuch as a large part of this work was being done by Portable Pneumatic Drills, the introduction of the Electric Drill for heavy work naturally raised the question of Portable Pneumatic Drill, vs. the Portable Electric Drill, and I

will endeavor to briefly give you a comparison of these two types of Portable Drills.

The first item considered was that of operating costs. It is a known fact that the cost of producing compressed air is considerably higher than the cost of producing electric power. These costs will, of course, vary in different plants, depending upon the nature of equipment and methods employed. Under average conditions, however, it has been found that the cost of operating Portable Pneumatic drills is about five times greater than the cost of operating Portable Electric Drills, of the same capacity. This does not take into consideration the losses in transmission of these two kinds of power. The loss in transmission of compressed air, due to leaks in air line, is considerably greater than in the transmission of electric power. There is also considerable annoyance caused by freezing of air lines in cold weather, particularly so in yard work.

The efficiency of these two types of Portable Drills is next considered. The efficiency, as referred to in this case, is based on the ratio of input of power to power delivered at the spindle of the drill.

Based on numerous tests made in the larger sizes of drills, the Pneumatic Drill, operating under average shop conditions, will have an efficiency of approximately 20%; while the Electric Drill, of corresponding size, will have an efficiency of approximately 75%. On one test made in one of the plants in the Pittsburgh district, a Pneumatic Drill, weighing approximately 65-lbs. consumed 75 cu. ft. free air per minute at 85-lbs. pressure, (which is equivalent to approximately 15 h.p.), and delivered 2 h.p. at the spindle at 112 r.p.m. The Electric Drill, weighing approximately 75-lbs., consumed 4.6 h.p., and delivered 3.4 h.p. at the spindle at 155 r.p.m.

In the smaller sizes of Electric Drills, the efficiency is not as high; the smaller drills, however, will show an efficiency ranging from 45% to 65%, depending upon size and type of motor used.

The gradual increase in the use of Direct-Current Drills created a demand for similar type Drills for alternating-current. The induction type of motor was first employed, but owing to the increased weight and limitations in speed of

this type of drill over the direct-current type, its use was somewhat limited. This, however, brought about the development of the Universal type of drill.

The Universal type of drill will cover a fairly wide range, inasmuch as it will operate on single-phase, alternating-current, of sixty cycles or less; and also on direct-current, of the same voltage. This type of drill proved to be considerably lighter in weight than the induction type, and

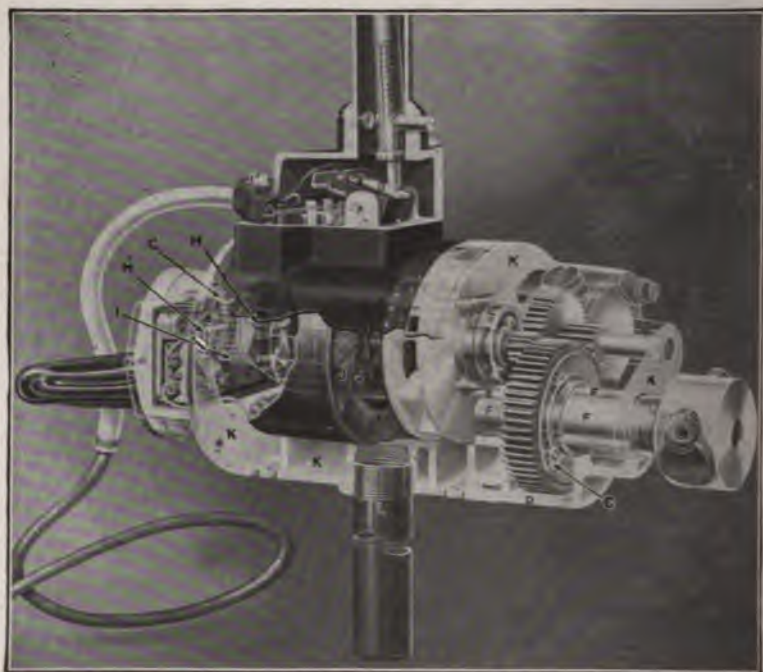


Fig. 1

equally as flexible in its application as the corresponding sizes of Direct-current Drills. The Universal Drill, however, does not attain as high a point of efficiency as the Direct-Current type drill, but is more efficient than the Induction type drill—size and weight considered. In the smaller sizes, the Universal Drill has proven to be a very valuable and fairly efficient drill. But in the larger sizes, they have not as yet, proven as efficient as corresponding sizes of drills, of the Direct-Current type.

Fig. 1, shows the internal construction of a $\frac{1}{2}$ -in. capacity Electric Drill.

The Portable Electric Reamer is practically the same as the Electric Drill, except that in some cases it is designed for a somewhat higher spindle speed, and is used chiefly in

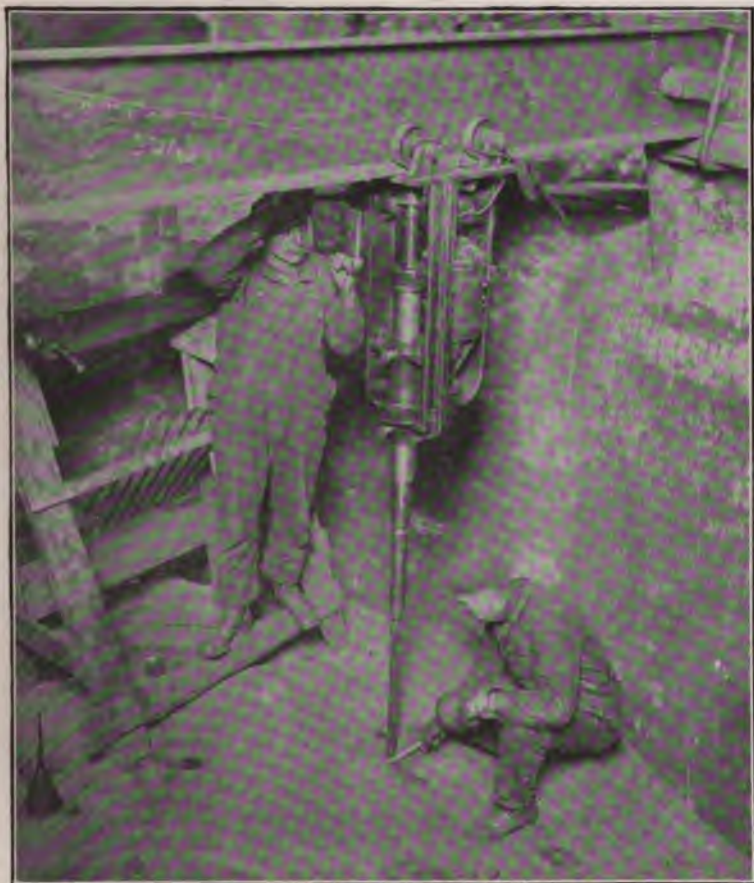


Fig. 2

bridge and structural plants, car shops and shipbuilding plants for reaming work.

The Portable Electric Grinder is of a somewhat different type from the Electric Drill in that a constant speed motor is employed for the reason that it is essential to maintain a proper cutting speed, which, according to wheel manufactur-

ers, is based at approximately five thousand (5000) peripheral feet per minute, and this could not be maintained with a variable-speed type motor.

The application of Portable Electric Tools are many, not only in the iron and steel industries but in other branches of industrial work. A recent application, and one that I



Fig. 3

believe will be of special interest to this Association, is the Electric Salamander Drill. Fig. 2, shows a machine of this kind, operating in one of the mills of the Youngstown district. This machine drills at the rate of approximately 1-in. per minute. The average depth of hole necessary to drill in a salamander is about 50-in. This depth will, of course,

vary, depending upon shape of salamander. Several sizes of drills are used. The first drilling is done with a $2\frac{1}{2}$ -in. drill bit, and hole is drilled to a depth of 12-in. to 14-in. A size smaller bit is then used for another 12-in. to 14-in. and so on, until the final drilling, which is done with a $1\frac{1}{2}$ -in. bit. The reason for using a smaller size drill bit with each change of drills is to eliminate side friction of the drill as much as possible. The average time for drilling a 50-in. hole, including time for changing drill bits, etc., is approxi-



Fig. 4

mately one hour and twenty minutes. This is about one-fifth the time required by former methods. Time being a very important factor around a blast furnace, this saving can readily be appreciated.

Fig. 3, shows the Electric Drill used for furnace tapping. The type of drill bit used is made from $1\frac{1}{4}$ -in. to $1\frac{1}{2}$ -in. round bar steel, about $3\frac{1}{2}$ -ft. of which is flattened to $2\frac{1}{2}$ -in. across the flat and twisted; the other end of the drill being fitted to the socket in the machine. The drill bit should be

from 10-ft. to 14-ft. long, (depending upon conditions at the blast furnace.) To facilitate the operation and relieve the operators, the Electric Drill is suspended from above with wire cable, running over two pulleys, with counterweight slightly heavier than the Electric Drill. The entire tapping operation is done in approximately five minutes. The hand method of furnace tapping usually requires from twenty to twenty-five minutes.

Small and medium size Electric Drills are extensively used around steel mills, by the electrical and mechanical departments, for repair work, installation of new machinery,



Fig. 5

installing safety guards, etc. It is also being used for drilling switchboard panels. For this latter work, however, a slow speed type of drill is necessary. The Electric Drill is also successfully used for wood-boring work, and in the erection of staging or false work.

The Electric Drills and Reamers are also successfully used in steel car plants for all classes of drilling and reaming, in freight and passenger car construction.

The Electric Reamer is extensively used in bridge and structural work. No doubt, it will be of interest to know

that over one hundred (100) of these Portable Electric Tools were used in the building of the Panama Canal.

Fig. 4, shows the Electric Reamer in operation in a bridge and structural plant. This is, no doubt, the most severe class of work that a Portable Electric Tool is called upon to do, as it oftentimes consists of heavy reaming through several thicknesses, and considerable metal has to



Fig. 6

be removed. Besides the economy in operation, the Electric Reamer will also show an increased output over other types of Portable Reamers. The increased output on this class of work being approximately 30 to 35% over that of Pneumatically Operated Portable Reamers of corresponding sizes. The reason for this is, that the Electric Reamer with its variable speed motor, operates at more uniform sustained

speed than the Portable Pneumatic Reamer, and is more flexible in its application.

Small and medium size Portable Electric Tools are also successfully used in automobile and truck building. Fig. 5, shows the Electric Tool on automobile frame work.

In recent years, a number of devices for use in connection with Electric Drills, have been introduced. Fig. 6, shows an Electric Drill mounted in a drilling stand, which,

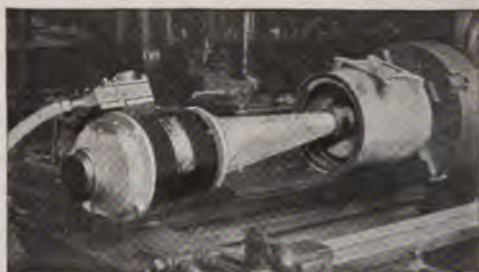


Fig. 7



Fig. 8

to some extent, fills the requirements of a Portable Drill Press. The Electric Drill is securely held in place by means of the adaptor plate. The drill can readily be removed from the stand and used in a portable way for work around the mill.

Portable Electric Grinders may be divided into two classes; namely, Aerial type Grinders and Machine or Lathe type Grinders.

The Aerial type Grinder, as its name implies, is used for all kinds of portable grinding, such as grinding castings, steel plates, etc.

The Machine or Lathe type Grinder is successfully used on various classes of work, such as grinding lathe centers, grinding blanking dies when mounted on a shaper, face mill cutters, inserted blades of milling cutter and various kinds of internal grinding.

Fig. 7, shows a Grinder doing internal grinding work; while Fig. 8 shows a somewhat different style of Grinder, mounted on a milling machine, grinding inserted blades of milling cutter.

Very often the work to be done by the larger sizes of Electric Drills or Reamers is located in out-of-the-way places that are not easy to reach, and oftentimes the workmen are required to stand in a strained position to do the required work. These strained positions are sometimes such that it does not require much of a push or jar to throw the workmen off balance, and probably result in a fatal fall. If the Tool jams in the work or is suddenly twisted, the resultant jar may be great enough to throw the workmen.

To guard against this and protect the workmen in these remote places, a separately mounted circuit-breaker panel is used in connection with the switch on the handle of the machine.

This circuit breaker is tripped automatically before the tool stalls, thereby cutting out power to the motor and protecting the tool and workmen. To reset breaker, it is only necessary to open the switch on the tool handle, and to restart the motor the same switch is closed again. The workmen do not have to leave the work to reset the circuit breaker.

This circuit breaker is in the form of a single-pole shunt contactor, working in connection with an electrically reset overload tripping relay. This relay has two coils, one connected directly in series with the motor, and the other directly across the line in series with a protecting resistance.

Whenever an excessive current is taken by the motor, the series coil will cause the relay plunger to pull out and open an auxiliary switch in series with the single pole contactor. This contactor breaks the power circuit to the mo-

tor; in the meantime, the relay plunger is retained in the tripped position by the coil which is connected directly across the line. When the switch on the machine is open, the circuit to the retaining coil is broken, which will allow the overload relay to reset itself. The contactor will now close, but the motor will not start until the switch in the handle of the machine is closed.

Under normal operation, the tool is started and stopped by the switch in the handle. Only two wires run to the switch; therefore, a duplex conductor is all that is necessary to the tool from the circuit breaker box. This conductor carries all the current taken by the motor.

The history of the Portable Electric Tool, from an operating standpoint, has been such that it has shown in a number of plants where unsatisfactory results were experienced, that same was due, to considerable extent, to the fact that drills were not properly maintained. By this is meant that if a drill showed an indication of improper running conditions or abnormal heat, no attention was given to the drill. It was allowed to work along in its usual manner until it reached a point where it either clogged up or damaged the windings. Such conditions, of course, have been very unfair to the Portable Drill.

These conditions, however, have greatly improved in recent years, some plants having regular periods for inspection of Portable Tools; and when a drill is found to be showing trouble, it is immediately removed from the line and the trouble rectified.

In plants where such a system is carried out, the Electric Drill has proven most satisfactory, not only because the operating force was allowed to accomplish full benefit of the drill, but also in the life of the machine.

Electric Tools, working at a disadvantage and not properly maintained, cannot produce the highest efficiency and greatest amount of work. This is well in line with other classes of electrical machinery which have duties to perform. When properly maintained, the best results are realized—improperly maintained, it is a case of take what you get.

The Portable Electric Tool has been so standardized that each component part is a self-contained unit; namely,

the armature and motor housings, the top head assembled, the gear case assembled, and the switch mechanism with complete switch control. These parts are all a unit in themselves, and are absolutely interchangeable.

DISCUSSION

W. T. Snyder: I notice that Mr. Andresen's paper refers to the increase in efficiency of a portable tool. It is my opinion that the tool builders should not pay so much attention to efficiency as to ruggedness and reliability, and light weight in the case of portable tools intended for the steel industry. I believe these points are more important than efficiency or even accessibility in the case of the smaller tools.

F. A. Wiley: We find a great many uses for portable tools in miscellaneous repair work, such as drilling stray billets, for sampling, drilling tapping holes in the blast furnaces, and general repair work around the mills. The portable electric drill is fast displacing the air drill on account of the greater efficiency of the electric drill. The great loss in the transmission of air gives the electric tool preference over the compressed air operated tools, especially drills, reamers and grinders. The electric hammer has not yet been developed to that state of perfection where it will do the work performed with the air riveting hammer.

We find in practice that the method of lubrication is a very important part in the design of the electric drill. All transmission gears should run in grease. We have had some experience with portable electric drills using both oil and grease lubrication and we find that where the oil lubrication is used there is always a tendency on the part of the workmen to flood the motor with oil which will always cause trouble, while on the other hand we have very little trouble where grease lubrication is used because the workmen who use the tools are not required to do any oiling.

In selecting a portable electric drill for drilling tapping holes in a blast furnace, it should be a drill that is designed for a low spindle speed, not more than 100 or 120 r.p.m. In

using a high speed drill for this class of work you are liable to have considerable trouble if the notch clay contains any stone or cinders, the men operating the drill being very likely to do a few stunts that are not on the program when the drill comes into contact with stone in the clay. The portable electric tool has become a necessary article in most plants at the present time. We also find that where workmen have been accustomed to operating air tools and then go to using electrically driven tools, they require some education on how to use the motor-driven tool. If the workmen desire to force the air tool it will merely stop and no damage is done, while in the case of the electric motor-driven tool if it is forced too much it will soon mean a job for the repair shop.

C. B. Coates: The gentleman who preceded me stated that he preferred a slower speed and this is, to a large extent, accomplished by the compound windings, as the shunt field holds down the free speed and reduces the ratio of no-load to full-load speeds.

As Mr. Snyder said, the question of efficiency is not vitally important, but the matter of maintenance cost and the reliability to run it any time when required is important.

The series motor as mentioned by Mr. Andresen has proven very satisfactory for this class of tools, but the speed characteristics of this type of motor cause considerable variation in the cutting speed of reamers on different classes of work. For instance, when reaming thin plates the area of the surface to be cut is comparatively small resulting in a high speed, due to the small amount of power required. When reaming very thick plates with the same size of reamer, much more power is of course required and the cutting speed is therefore a great deal lower. With the straight series motor, the variation in speed between no load and the heaviest loads is 50% or more. In ordinary reaming operation the tools are not stopped in going from one hole to another, resulting in the motor attaining its maximum free speed between holes causing extra wear on the bearings of the tool. It also has the disadvantage on drilling operations due to the fact that when the drill breaks through the work the motor will speed up on account of the smaller load, burn-

ing the points of the drill bits. I believe that in the larger sizes of drills and reamers, a compound field winding with a large percentage of series and sufficient shunt windings to hold the speed down at no load is a much better proposition as it not only saves the motor from the excessive speeds, but also the cutting tools. Experiences of the past year or two with this type of machine have proven very satisfactory. The shunt fields are placed on pole pieces independent from those which carry the series windings and therefore, can be most thoroughly insulated.

In regard to the comparison of pneumatic and electric drills, there is one point that I think is often overlooked. The air drill when supplied with a drilling tool or reamer smaller than the maximum size for which the tool is intended is often operated with a wide open throttle in order to get high speed. A piston air drill operating in this way consumes much more air than when running at full load at a slower speed, due to the fact the cylinders have to be filled with air a great number of times. From this you will see that the efficiency curve of the air drill drops off very rapidly below full load. On the other hand the curve of a motor of a well designed electric tool is quite flat, from $\frac{1}{4}$ to $1\frac{1}{4}$ times the normal load. Mr. Andresen states that the cost of operating pneumatic tools is about five times greater than the cost of operating portable electric tools of the same capacity. He then gives an example showing that the efficiency of the larger sizes of pneumatic tools is approximately 20% and that of the corresponding electric tools about 75% or three and one-half times as efficient. I presume that he takes into consideration that the cost of producing the air is considerably more than for electricity which would account for his statement that it would cost about five times more to operate the pneumatic tools. This is the generally accepted idea on the subject. The more recent designs of pneumatic drills in the large sizes are very much more efficient than the older types and the latest design capable of developing from three to four brake horse power show an efficiency of approximately 30%, which would reduce the ratio of costs of operation between the two tools. The question of efficiency of cost of operation is not such an important one except in large installations, and as a general

proposition the convenience of obtaining power for the electric tool gives it a great advantage over the pneumatic tool.

Mr. Andresen refers to circuit breaker panel used in connection with the larger electric drills and reamers. A new type of breaker is now being placed on the market which operates without the relay referred to in his description. The operating mechanism of this breaker is simply a solenoid with two windings, the series winding acting as the overload coil to draw up the plunger and open the circuit and the shunt winding acting on the same plunger is connected across the break so that when the breaker is open the shunt coil is in series with the winding on the electric drill and serves to hold the plunger in off position. The releasing of the switch on the drill breaks the shunt circuit and then the plunger is returned by a spring. A dash pot is provided to take the first momentary rush of current in starting the tool. This device is comparatively small, being about 15-in. long x 5-in. wide x 5-in. deep.

George W. Richardson: We have tried a great many reamers in our bridge shop, and I must say that in the case of electric reaming we never had results which were satisfactory until the automatic switch came out, and since then our electric drills are doing very nicely. In fact, we are putting them in and doing away with the air drills as fast as we can.

Years ago, when we tried a great many of them, the electric drill was not so useful. I used to think we should have an electric drill made on the order of the air drill, on account of the overload from sticking the drills in the work. I am mighty glad, however, to see that this overload device has come along and we are relieved of the troubles we had before. Formerly we could use the air drill and ream out five holes to one hole reamed out by an electric drill. At the present time I think that is reversed.

The electric drill as made today is a great improvement, still we should go a little further if we can, and keep the weight down. As Mr. Snyder said, we would like to have ruggedness in the drill, but at the same time light weight. We, at the present time, examine our drills every two weeks. We take them in and give them an overhauling, and under that method the drills are doing very well.

Some of our people at Ambridge and other plants in the American Bridge Company have had more experience with these drills than I have had at Pencoyd.

F. D. Egan: There is one point brought up by Mr. Andresen in connection with spindle speed, that is the trouble of getting high-speed tool steel. It is almost impossible with the present speed of electric drive to use low carbon steel. We had a large amount of work on which we were using electric drills but set them aside and substituted air drills, thereby obtaining better speed control. If we could get gear changes in some of the older drills it would help matters out.

W. T. Snyder: Why not go a step further and get variable speed motors?

Fred H. Woodhull: For a number of years we have had a few drills in operation, and we have experienced some of the troubles spoken of. There was one thing in particular, which has not been spoken of here, with which we have had a great deal of trouble, and that is in connection with the brush-holder insulation and the insulation around the commutator end of the motor. We have had a great deal of trouble with that, as well as with the starting and stopping switch.

The matter of speeds has been spoken of by Mr. Egan. We obtained and put in use two high-speed drills a short while ago. They were of small size for opening up tell-tale holes in staybolts of locomotive fireboxes. We got them with the idea of using the high-speed steel drills but when it became so very hard to get the high-speed steel, we had to substitute the standard carbon drill and the consequence was we had trouble from burning the drill and we had to go to a slower speed drill.

C. S. Lankton: The principal trouble I have experienced is that the people operating the drill try to operate the drill too hard. We have had one or two armatures burned out.

John F. Kelly: Is the circuit-breaker, which automatically trips off, in a fixed position or is it portable?

A. M. Andresen: Portable.

John F. Kelly: Can one workman carry it and the drill?

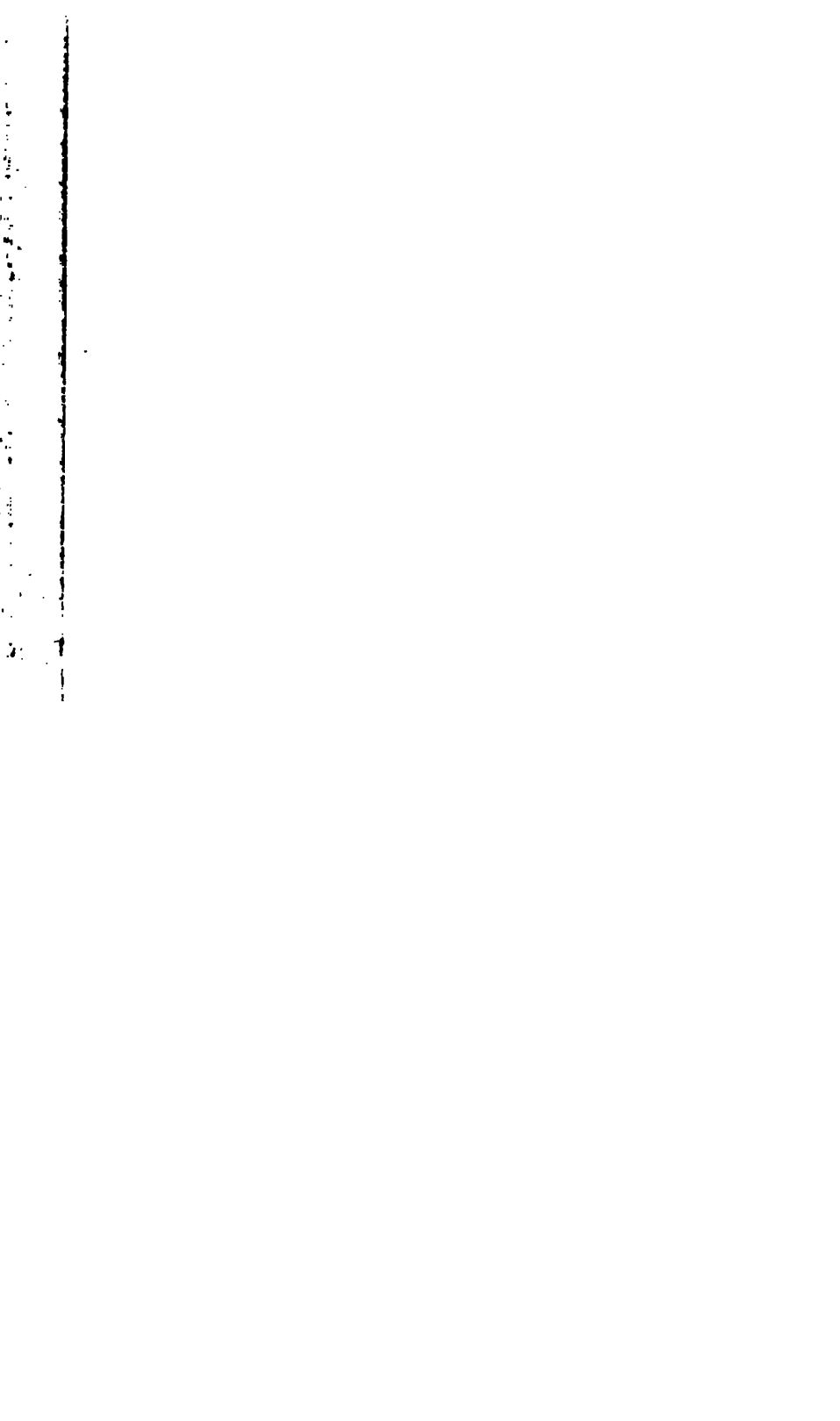
Frank J. Burd: In answer to Mr. Kelly's question, the circuit-breaker consists of a shunt contactor in conjunction with an overload relay, main knife switch and fuses, all mounted on a slate panel. Very frequently this panel is put into an enclosing case and can be readily carried around with the drill. The weight of the panel enclosed as described is approximately 50 pounds.

In some instances, the panels without the enclosing cases are mounted along walls or fastened to pillars. In these cases a plug outlet is mounted beside the panel or at other desired locations. The workman then simply plugs in with the extension terminals attached to the drill or reamer.

The use of a dash-pot on the over-load relay has been referred to. It is my opinion that the addition of a dash-pot or other delaying attachment to the overload relay is a step in the wrong direction. One of the principal objects of the overload relay is to instantly stop the motor in case the tool becomes "stalled." This might happen while the workman is in a strained position in an inconvenient location, and if the motor still continues to exert torque after the tool stalls, it can readily be seen how the workman may be thrown and possibly seriously injured. A dash-pot, or other delayed action, on the over-load relay would be a detriment in this case, rather than a help. That a dash-pot is not desirable on the overload relay of these breakers, has been proved by actual tests, therefore the scheme has been abandoned.

A. M. Andresen: I believe that some of the trouble experienced in the plants is due to the use of too small a machine for the class of work which you have in hand. Oftentimes you will want to use an electric drill to take the place of a pneumatic drill. We must not lose sight of the fact that the electric drills, the medium and larger sizes, especially, are heavier than the pneumatic drill, and in choosing a drill for the work do not choose it by its weight but by the capacity which the machine has to correspond to that work. In the medium and larger sizes of electric drills, they will run, possibly, 20 per cent heavier than the pneumatic drill.

The point raised by Mr. Coates on the compound winding for larger machines no doubt would work out all right. The advantage, of course, on the series type of motor in the electric drill is when you use it for variable classes of work.



OBJECTS AND SCOPE OF THE A.I. & S.E.E.

By W. T. SNYDER

To begin, I want to ask the support and co-operation of the members on behalf of myself and the other officers of the Association, with which we feel sure that the Association shall continue to progress during the coming year.

I have had more or less intimate connection with the affairs of the Association prior to my election as Secretary, and along with the duties of Secretary. The experience I have gained has enabled me to form certain opinions or views in regard to the affairs and policies of the Association, and while, no doubt, some of them will be contrary to your own ideas, nevertheless I will outline some of them as briefly as I can. Some of the points we will dwell on are the objects, aims and make-up of the Association. We will consider some of the things that we hope to accomplish during the coming year, some of the things that we think should be done, and also touch briefly on a few things we think should at least be given consideration.

The object of the Association at its inception, as stated in the Constitution, was the advancement of the application of electricity to the Iron and Steel industry. Now, it is a fact that we are confronted today with problems that were foreign and unknown to the industry when the Association was first organized; and it is my impression that the present achievements in electrical applications in the industry are due, in a large measure, to the pioneer work and the later development work of the members of this Association. However, we cannot rest on what has been done in the past; while a great deal has been accomplished, it is small when

compared to what is yet to be done, and one of the chief requirements of the organization is to keep pace with the progress in our profession.

I have made certain investigations and analyses which indicate to my mind that the Association, insofar as the active membership is concerned, is not even now keeping up with the growth of the industry. I believe our active membership is not representative of the industry.

The following data, compiled from the Iron & Steel Institute directory of 1912 and our present Membership List, is submitted for the purpose of comparing the number of blast furnaces in different localities with the number of active members we have from such localities. In Pennsylvania there are 159 blast furnaces and we have 59 active members, there being 48 active members in the western part of the state and only 11 in the eastern part. In New York state there are 33 blast furnaces and we have only 3 active members. In Alabama, quite an iron and steel center with about 45 blast furnaces, we have but one active member. In the immediate vicinity of Chicago, there are about 50 blast furnaces and only 11 active members. With the exception of the Pittsburgh district, the Association is but poorly represented in the number of active members from the localities mentioned above.

The above data seems to indicate that the Association is in a more healthy and flourishing condition near the center of local activities. Nearly all the activity has been centered about Pittsburgh. If this Association is a good thing for the members engaged in the Iron and Steel industry in the Pittsburgh district, it should be just as good for the electrical men in other industrial centers, but it seems there is not the same interest and that the Association is not extending the same benefits to the members in the other steel centers of the country that it is in the Pittsburgh district. As above mentioned, the eastern part of Pennsylvania is represented by only 11 active members—a relatively small representation compared to the western part with 48. I am glad to note Mr. George W. Richardson, from the eastern part of the state, is with us, particularly so in view of the fact that he has been appointed a member of the Member-

ship Committee, as he will now have proof of the fertile field he has to work in.

In the above tabulation, blast furnaces only are compared to the membership, and had the other plants that are allied with the industry been included it would, no doubt, more forcibly show the lack of representation of our membership.

At the nine Conventions held since the Association was organized, I found that there were 146 papers presented and out of this number, only 30 were furnished by active members—a little less than 25 per cent. These 30 papers were furnished by 20 different authors. Some members have contributed as many as four papers, others three papers, and others two. The active members are furnishing only a small number of the papers, and, outside of the executive work, they are taking but slight interest in the activities of the Association.

Out of 146 papers presented, covering thirty subjects, 71 papers embraced applications, 55 were of a descriptive nature, 17 were of general engineering nature, and 3 were general. Again, 28 papers were on control, 26 on motors, 17 on prime-movers and generators, 6 on safety, and 5 on cranes.

While we must acknowledge that a great deal of credit for present achievements is due to the early pioneer work of the Association, we do not have the time, nor is it essential at this time, to go into details regarding the improvements that have been made. I believe we are, and should be, more concerned about the present and the future of the industry and the policy of the Association. I believe the statistics, just given, indicate the value of local meetings in the various industrial centers, and I would strongly urge the establishment of four local sections. I believe the best fields would be: Chicago, where they have been carrying on local meetings at frequent intervals; Cleveland, where preliminary steps have already been taken toward starting local meetings; one in the eastern section of this state, possibly Philadelphia, or thereabouts; and continuing the Pittsburgh local meetings. This would make a total of four local sections of the Association.

The question comes up of how a change of policy could be carried on with respect to the Association finances. The

Association, as it is being conducted, is not self-supporting—if we exclude the assistance we receive in the way of advertising space in the Proceedings. Considering only its legitimate resources, it is not self-supporting, and if these additional sections are inaugurated, they will entail additional expense. The legitimate resources are the entrance fees and the dues, which at the present time, with the present membership, amounts to \$2,300.00 a year. The operating expenses of the Association could be kept to \$3,100.00 per year. We would, therefore, require additional revenue to the amount of \$800.00. There are two possible methods of increasing the resources of the Association; the first, as has been suggested by a prominent associate member, would be to revise the qualification for active membership, so that men that are now only eligible to associate membership but are just as properly steel mill electrical engineers as any of us—the men that come out to the works and help us in the determination of methods, the selection, application and maintenance of the apparatus that we require in our industries; men that are engaged in almost purely engineering work, even though working for commercial companies; it has been suggested that these men could be admitted to active membership with all the privileges, excepting, possibly, that of holding the office of president. This would tend to increase the proportion of active members. It is possible that it would increase the standing of the organization. It would admit to the participation in executive and administrative affairs of the Association the men that are possibly better trained by experience for doing this work than is the average steel mill engineer.

The associate grade would remain unchanged, admitting the men whose activities are purely of a commercial nature, but allied with the iron and steel industries. In looking over the membership list, there are a large number of men who could qualify for active membership under this plan.

The second method would be to allow both grades to remain as they are and increase the dues of the associate member to, say, \$7.50 a year. The running expenses of the Association, with four sections, will amount to at least \$3100.00 a year, which, with the total membership of 350 we have today, is an average of \$9.00 per member. The

active member now pays \$10.00 a year—the associate member pays \$5.00.

Either of these plans would increase the legitimate resources of the Association to within about \$200.00 of the amount necessary to finance the organization. The balance could be made up by continuing our present policy of accepting a limited amount of advertising in our proceedings. Either plan would permit conducting local sectional meetings in those four industrial centers already mentioned. The inauguration of these local meetings would result in an increased active membership that would make possible in the future the establishment of a central office with a permanent secretary. These are two things that the Association needs right now—if it is to extend the field of its operations.

In doing this you are going to increase the business end, that is, the amount of work that is necessary for carrying on the Association's affairs, beyond the point where it can be satisfactorily carried on by voluntary work. It is now about a dividing line. It is almost too much to be handled by voluntary work and the membership is not large enough to justify and finance a paid secretary that will devote his whole time to the interests of the Association.

The establishment of these local sections would permit the selection of the governing officers from different industrial centers, instead of confining them to one district as has been the custom since the inception of the organization and which has been necessary so that the officers could get together and carry on the business of the Association at a minimum expense. It is my opinion that the Association cannot obtain the best results by continuing, in the future, the methods of the past.

As we have said before, the original object of the Association was the application of electricity to the iron and steel and allied industries. We have gone beyond the confines of this restricted obligation and the trend is plainly indicated by our membership list; we have members who are plant managers and assistants, plant superintendents and assistants, chief engineers, mechanical engineers, steam and hydraulic engineers, safety inspectors, and representatives of

the state government. It is again shown by the varieties of subjects upon which the Association has deliberated.

The object could now be defined in other words, possibly, "the advancement of the Iron and Steel industry by the application of energy in its most useful form," which, in the main, will be found to be electrical energy.

It has been suggested that the scope of the Association be broadened to take in the electrical men of other industries, outside of those allied with the iron and steel industry. Any reconstruction that would be taken up, I believe, should take into consideration this feature. While we are proud of the exclusiveness of our Association, which is boldly proclaimed in the name of the organization: "Association of Iron & Steel Electrical Engineers," nevertheless the modern trend is toward centralization, the incorporation of small units into larger organizations, with their consequently increased economy of operation.

Again, the problems of the electrical men engaged in the iron and steel industry, are almost identical with that of the electrical men in other industries, such as wood-working, glass, leather, textile, flour-mills, cotton-mills, and almost all other lines of industry. There are the same problems of generation, transmission and utilization of energy in the form of light, heat and power. It is my impression that the time has come when this Association, by its members, should shape the affairs and policy of the organization to conform to the trend of the times, which is toward the universal application of electrical energy almost to the exclusion of less useful and efficient forms. Those having to do with directing its affairs should set a mark well into the future, looking forward to the day that Dr. Steinmetz predicts—when the country will be covered by a network of transmission lines; when water-power of the Rocky Mountains will help roll steel in the eastern states, at the same time helping to grind flour in the central states; when the electrical man, as we know him, will have far greater responsibility than have most of us today.

This Association should be shaped with the thought in mind that in the future there will possibly be three large engineering associations in the industrial field. One, possibly, would be composed of men that are engaged in science

and invention, and the type of men in this association would be men like Edison, Steinmetz, Carty, Brashear, etc. Another organization to be composed of men engaged in the application of energy to the different industries, making use of the apparatus, appliances and methods developed by the other organization, and including the steel-mill electrical engineer of the future. The third organization to be composed of the captains of industry; the Dinkeys, Schwabs and Garys of the future, engaged in the more weighty problems of capital and labor.

I have outlined what, to my mind, would be the proper course to pursue in directing the activities of this Association. It seems to me that, during the coming year, the thing of most importance will be the policy of the Association. I believe it is not of as great benefit as it could be—I believe that is is not well enough represented throughout the industry, and I would like to have the views of some of the memembrs.

DISCUSSION

G. W. Richardson: I coincide with our president's remarks. I think, myself, we ought to try to broaden out. The eastern Pennsylvania district, I might say, is not well represented in this Association. Somehow or other, the members we had over there did not seem to attend. I have had the great pleasure of attending every annual meeting of this Association from the start, and I hope to continue to attend them at least.

I was very fortunate in that I happened to be in town today, so as to be at this meeting. I might say, in regard to starting the monthly meetings in our district, I will take up the question with the different steel plants around there, Bethlehem, Eastern Steel Co., Phoenixville, Allentown, and those places, and see if I cannot get those fellows interested. We could hold local meetings the same as you do here. It would only take about an hour's run to get down to Philadelphia, and I think it would be very interesting. I, my-

self, would be perfectly willing to hold those meetings, or try to hold them. About three Saturday nights in a month, my time is taken up by other organizations, but there is always one Saturday night open, so I might be able to help out. I have not given any thought to that subject until I attended your Association meeting today; and since it has been brought to my attention, I will see what I can do in that line of work—see if I can stir them up to local meetings, and if we get local meetings down there, as you say, I think it will have a tendency to have those members, or former members, take more interest and come back with us again. I will do whatever I can in my line to help the Association.

W. T. Snyder: We are certainly glad to hear those remarks from Mr. Richardson. At the same time, they are nothing more than could be expected, knowing Mr. Richardson as we do. He has always been one of the standbys of the Association. If we can get one hundred other members like him, the question is solved.

J. F. Motz: I am glad to see you have such big ideas for the Association, but for the immediate requirements I would like to see you stick for a while to the Association of Iron and Steel Electrical Engineers. I believe you will get the assistance of all associate members by leaving them as they are today. To stimulate the activities among the active members, I would like to see you take into the Association more of your foremen and active fellows among you; a lot of them are college men. If you don't want to make them active, advance your present membership to Fellows, or whatever you like, and put them in as members.

I would like to see more iron and steel fellows right in the organization, then hold your local meetings, and, if possible, hold meetings at different plants throughout the various districts by allowing three or four different plants to get together and call a meeting just among themselves for the Association, just as you have done in your regular organization. This would help out on your annual paper and strengthen the proposition, as your members would get more into step with the thing in getting up and giving papers and by having some part along that line. That is one of the reasons I would not like to see you take in the Associate

members—which consists mostly of salesmen—as active members. I think the situation as it stands today cannot be improved upon, and I think it is one of the reasons for the great success of the organization.

W. T. Snyder: I was only looking ahead. I did not mean to convey the impression that we wanted to start right in on that now. What I meant was that it seemed to be the trend of things that eventually the large number of relatively small engineering associations would get together somehow. We have already heard a discussion of that same thing in our own ranks. Some of the larger organizations have their eyes on us now.

L. F. Galbreath: I think it would be better to take up some of the ways that would put it before the steel men as a business proposition. The more you are familiar with the other man's product the better you can talk to him. So if you put it up to the steel men who haven't representatives in the Association at the present time, I believe we could secure quite a number of new active members in that way. Go into the different localities where we are not represented, go after the president of the company and put it up to him as a business proposition. Show him what improvement has been made during the last few years. Show him what his company would gain if its men were associated with other manufacturers, because as it is now with those people, they have to depend on one man, where if he belonged to the Association, he gets the improvement of 114 active members. There is a way you can get at that which might do some good. I do not believe it would take three months. Send a committee to each one of these steel mills and put it up to them as a business proposition. Put it up to the American Iron and Steel Institute, so the big men will get hold of it and get it under discussion there.

L. Hommel: I rather agree with Mr. Motz in one idea—I believe that you can get more good by retaining your identity such as it is now. I believe that one or two years ago, the question of merging the A.I. & S.E.E. and the American Institute was discussed. It seems to me to be a mistake to take that step. In line with Mr. Galbreath's suggestion, it occurred to me that it might be a good idea to have extra copies of your proceedings printed and offer to sell them at

a very low figure to such men as would be eligible to become members of the Association. I believe that would show them how valuable membership in the association would be to them, and they would realize what they are losing.

W. T. Snyder: I agree with Mr. Hommel that we should not lose our identity, at least at the present time; we should not amalgamate with any other association. I merely said in my remarks that the tendency was no doubt in that direction.

Clark S. Lankton: I want to be a progressive. I want to be a man who can see into the future, but I am a little skeptical about soliciting new members from other industries other than the iron and steel industry. I believe that this association has been very successful and I am proud of its organization. I am proud of the success that it has had and I do not want it to stop where it is. I realize that the field for membership is limited because we have only one industry to draw from, yet if we leave this particular line of activity then I believe that we are invading a field that has been taken up by the American Institute. I do not think that we should become competitors of the American Institute.

Mr. Snyder has shown that there are a good many loose ends that could be connected to the Association's betterment. The Pittsburgh district has been very well canvassed, but there is still scattering material. The outlying districts are not represented in the Association as they should be. Now whatever activity we put forth should be such as to make it an object for the outlying districts to come into the Association.

We have had interesting local sessions and that undoubtedly is the key to the success of the Association in the Pittsburgh district, but now I believe we should consider what will help the western man, the eastern man and the southern man, so that our Association may be very broad, but yet be confined to the iron and steel electrical field.

E. Friedlaender: I do not wholly agree with our President's remarks; I think he is painting a little too black. I think our Secretary can show us that we still have some

money in the treasury. I also do not agree with him when he calls advertisements we have taken for our proceedings as not legitimate. The American Institute has three or four times as many advertisements in their monthly proceedings.

I think that to increase the membership would be a better way than to increase the dues of the members. For the last three or four years, we have only taken in members who came in themselves; we really haven't gone out after them. What we need is a very active membership committee. It is very hard for the active members, who work day in and day out at the mills, to get acquainted with other men; our associate members travel around the country and visit the various works. I think a good plan to increase the membership would be by getting every associate member that is a representative of a manufacturing concern to make up a list of men eligible for membership in his district, and send it to the membership committee, which committee will attempt to enroll these men.

This Association is only nine years old, and cannot afford to hire a paid secretary at present, but we are getting along. The biggest trouble in my opinion is the little interest shown by the largest part of the membership. It is really up to only the few who come here once a month to keep the Association active. The most money is spent for printing, and we do a lot of it; we print as much as any organization in the country, in proportion, and I think we ought to keep it up. There are lots of members who have never had a chance to attend our meetings and conventions and all they know of our proceedings is what they see in print.

I do not think we ought to branch out and take in other industries. We would lose our identity. This field is plenty big enough for us. What I would like to see is twice as many members. If each of you brings in one member a year we will be satisfied. I think it can be made self-supporting.

W. T. Snyder: When I referred to the legitimate revenues of the Association, I did not mean that we are taking money out of anybody's pockets. I possibly should have said the ordinary revenues, and we could consider revenue from advertising as special, or extraordinary.

M. B. Spaulding: I think the suggestion about the local meetings a very good one, but I think we might add one other district, namely, Youngstown. Youngstown has a large number of mills, and, possibly, members. I think you would be able to get as many together in Youngstown as we do in Pittsburgh. In regard to taking in the foremen in the mills, I think that is where we should look to for the increase in our membership. That of course could be taken care of by the companies that employ the men. As to the question of increasing the dues, I do not think it would be necessary, providing you get the additional membership. As to the printing and general expenses of the organization, \$3,100 seems rather a large item. How that is made up I do not know. It seems to me that it is rather a large item for the amount of printing and number of members.

Jas. Farrington: In the bringing in of our new members, or rather of educating those who are not familiar with our work, it would be well if we could interest in the Association the chief engineers of our own plants, the chief engineers and chief salesmen of contracting firms so that they would, in the designing of new apparatus, be more favorably impressed with our work and with the use of electrical work than in the use of steam and hydraulic; because there are lots of companies that haven't electrical men and rather than deviate and go into electrical work, they will continue to use steam and hydraulic. Then if we could get our members to turn in a card when they learn of new equipment to be put in, at the next monthly meeting this could be put before the Association.

It seems a great many members in their letters of resignation, say they haven't received any help towards the operation of their plant, or in getting better efficiency or ideas, because they have been unable to attend the annual conventions, whereas, if these were taken up at each monthly meeting and the minutes sent to them, they would get all the new installations, such as by-product coke ovens. The idea is to save new companies from running into the mistakes the rest of us have made. When any new plant is to be built, these men are generally called in and if they would let the secretary of the Association know that a new concern was contemplating a new installation, then if that plant was

not represented in our membership they could send to the general manager a copy of our proceedings along the line of the apparatus they expected to install, which would show the benefits of the Association and secure their electrical man as a member. But my suggestion is to leave the Association remain as an Association of Iron & Steel Electrical Engineers.

W. T. Snyder: For Mr. Farrington's information, and the other members, I might say a new special committee has been appointed this year, which is called the Progress Committee. One of the functions of the committee will be to act as a clearing house for such information as Mr. Farrington refers to, to keep the membership as a whole informed as to what is going on.

C. A. Menk: We all listened gloomily while Mr. Snyder was making his speech, and I think we have cause; because we can all see the interest that some of our members have taken. The Association seems to be a sort of after-consideration. I do not think there is anyone who takes interest in it who will not get proper value. From what I can understand, the Association at the present time is not self-supporting. That is not a good thing. If we were in business, it would only be a short time until we were in the hands of a receiver.

I do not think there is a man here who would like to see the Association dropped, and it will be dropped unless we take an active part in trying to build it up. The meetings in Pittsburgh, I believe, is what has held it together so far. Nothing has been done in the eastern end of the state, and nothing in Cleveland. I believe there were some meetings in Chicago. I understand we have about 60 members in the Philadelphia district east of the mountains. Now, there is no reason why they could not get together at least once a month and build up that end of the state. As for Pittsburgh, we can do a great deal more. I know we have men that would be benefitted by belonging to the Association, and when it comes down to costing this and that, we know it don't amount to anything; it just seems to be the lack of interest, because the men don't come.

Now tonight, and ever since the convention, there is quite a number I haven't seen from the Pittsburgh district.

That isn't right, because I believe every man that belongs to this gathering should come to every meeting. Many of them have their dues and expenses paid by their employers, and looking at it that way, I believe we do our company an injustice by not attending the meetings. We get some good, if it is only a matter of friendship, and nothing more. It looks to me as if we will have to liven up the Pittsburgh district and go a little farther. I would like to ask Mr. Richardson if it would be possible to get 40 of the 60 members together in Philadelphia. I believe a dozen members from Pittsburgh would go down there and give them some encouragement. Do you think so?

G. W. Richardson: I think so, yes.

C. A. Menk: That would be something. I do not know whether I would go to Chicago, because there is enough talent out there to put life into that district if they would. In Cleveland, some help might be needed. We ought to get 100 to 150 members this year. It would mean a special effort of every man here tonight to be on the lookout to spread the news. Unless all of us get busy, I believe we will lose by default.

I know it is a hard matter to get papers for all of the monthly meetings and for the convention. It takes a lot of hard work. I think Mr. Snyder and Mr. Friedlaender deserve all the credit, to a certain extent, for carrying the Association through for the last two or three years with very little help from the outside. I think we should put our shoulders to the wheel, and see if we can't boost it a little further along.

W. T. Snyder: Mr. Menk certainly has the right spirit. As for my doing 50 per cent. of the work, I want to say that we have others who are doing something; and some are doing a great deal.

Saul Lavine: I think the ground has been pretty well covered; but I for one, will pledge myself to get either an Associate or Active member for this year.

Jos. Breslove: In considering the advisability of enlarging the scope and membership of the Association, it is well to take note of the manner in which other engineering bodies have solved these problems. As a member of one of the large engineering societies, whose membership is

about 7,000, it is interesting to note that they were confronted with the same problems and through a recent, vigorous campaign the membership was greatly enlarged. Local sections were established in various parts of the country, and, while the membership has grown rapidly, it is questionable, however, whether it has resulted in greater benefit or satisfaction to the members of the society. Entrance requirements for members was very rigid at one time and I can remember when membership in the society was virtually a recommendation of ability. With the added numbers there are undoubtedly many who do not measure up to the original high standard and, consequently, it does not carry with it the same weight.

I believe it will be to the advantage of this organization to continue as a separate body of electrical engineers who are interested particularly in the iron and steel industries, that the active members be only those that are occupied in this branch of engineering, and that those interested in a commercial sense only, as represented largely by the sales engineers of the various manufacturing companies, still continue as associate members. This would eliminate the commercial spirit from imparting too great an influence on the active policy of the society. It would be well to introduce a third grade, to be known as "Junior Members," and men now actually employed in the iron and steel industry, such as assistants, foremen, etc., should be eligible for this grade. It would be from their ranks that promotions could take place, resulting in future increase of membership.

In order to increase the financial receipts, I would suggest that associate members and juniors, who after a certain period did not qualify for full membership, be assessed the same dues as members. This is the scheme that has been adopted in one of the larger engineering societies.

It is desirable to have a number of local branches established in order to carry on and stimulate active interest in the organization, but I am heartily in favor of having this society remain as a distinctly individual organization rather than merge with any of the larger institutions. This makes for greater interest amongst the members interested in a particular development, and is not likely to result in an unwieldy organization in which the majority of the members

are only slightly interested. A small number of earnest workers will accomplish much more than a large number who are only partly interested.

J. O. Corbett: I have absolutely nothing prepared, but listening to the talks this evening and the President's report, it has occurred to me that since this is the age of societies and this is a distinctly different organization, it would be rather a shame to lose its identity with any other association or name that might apply to electrical engineering. The President has said the associate men are more or less commercial, therefore, they should remain commercial or associate. I say this, especially in view of the fact that there is never any chance of my becoming anything else. It might be in order for them to pay more dues, as has been suggested, but I really think that the engineer is the fundamental member, and the associate member, even though he may be a credit, if he is interested commercially should be an associate member, or distinctive in some way.

Mr. Friedlaender said there was some difficulty in the active members knowing the others. Some of you active members possibly appreciate how difficult it is for us to get to know the active members at some of the mills.

I really think the Association, as it stands today, is in a very much better way to go ahead than if it makes any changes. Stick to the active member as a steel mill engineer, and to the salesman, or commercial man, as an associate member.

W. O. Oschmann: I do not know what I have gotten into, but listening to all the work that has been suggested for the secretary, I think it would possibly be better for him to give up his regular line of work and take up the line of the Association. The compensation could be doubled two or three times and still remain nothing—what it is now. I will say, though, that it requires a great deal of work, possibly two or three hours per day, and the work should be made as small as possible if an active member is supposed to carry it along with his regular work and not neglect anything. It is hard to do, and still I am sure we all appreciate the work Mr. Snyder has done in the past two years. I hope you will all help me as much as possible in trying to carry it along for the present year just as satisfactorily.

W. T. Snyder: This discussion has been very interesting to me. It seems to have created a great deal of interest among most of us. We will now come to the real part of our program. We will hear from a man who needs no introduction, is well known to all of us, and to everyone throughout the country, Mr. P. M. Lincoln, Past President of the American Institute of Electrical Engineers.



REMINISCENCES OF NIAGARA

By PAUL M. LINCOLN

Reminiscences are not so much the product of the mere lapse of time as they are of the progress of events. Development has taken place rapidly with the electrical engineer. Events have so transpired within the last twenty years that were we looking forward at the result as one to be attained instead of backward at the actual achievement, one might well be astonished that only twenty years have elapsed since the start of the Niagara plant. Measured, therefore, by the progress of events rather than the lapse of time the electric generators that began to deliver Niagara power in 1895 are at least grand-fathers, perhaps great-grand-fathers. Generations of electric machinery have come and gone since the installation of the first Niagara machines. Under these circumstances, therefore, I feel justified in jotting down the few recollections that follow because they are recollections of one of the earliest as well as one of the most important of all electrical developments.

Niagara marks an epoch in electricity. It stands as a monument to the greatest single step in advance that was ever taken in the electrical field. At the time the Niagara machines were designed, they were about four times the capacity of any alternators that had been successfully operated before. That in itself is sufficient to make the plant a memorable one.

There were many questions that arose concerning that installation that had to be worked out on the ground, things with which little or no previous experience had been gained. For instance little was known at that time about parallel operation of alternating-current machinery. The question as to whether the large new generators would operate suc-

cessfully in parallel was one that gave the engineers in charge of the plant no little uneasiness. How would the generator synchronize? Would they hunt after being synchronized? Could an unloaded machine be paralleled with loaded ones? These were a few of the questions that were asked and discussed, not so much because they were uncertain as because they were untried elements.

The feeling about this matter of paralleling was such that it was decided finally to wait until three machines were available before making any attempts to synchronize, one to carry the load and two on which to make experiments. This program, however, was never carried out. One day, shortly after first starting with commercial load and at a time when only the first two machines were available, a confused switchboard attendant made a mistake in throwing a switch and the deed was done. It was thus purely by accident that these machines were paralleled for the first time and the remarkable part of the performance was that the paralleling switch was closed so nearly at the proper time that hardly a mark was distinguishable upon the points of first contact. After it had been observed that the machines cut up no particular antics while operating on the same bus bars, our minds felt considerable relief on the score of parallel operation.

Immediately, however, another difficulty arose. Could the machines safely be taken out of parallel? Would the switching apparatus work successfully under these conditions? What would be the effect on the load? Rather than run any risks on these points it was decided not to use the generator switch to pull the machines apart in this case, but to postpone the use of that method of operating until after we had had an opportunity of trying it experimentally. Our method of getting the machines out of parallel on this first occasion was therefore to open simultaneously the field circuit breakers of both machines. The machines were then pulled apart and the load started up again on one of them. The problem of taking care of the discharge of the generator field had of course been thoroughly threshed out before putting any load on the machines; in fact before the machines were even started. To my mind this incident tells more forcibly than can any words the advances that electri-

cal engineering has made since that day. That such a state of mind was possible only twenty years ago speaks volumes for the progress of the art.

In any plant the starting period is one of vicissitude. Niagara was no exception. The first difficulties encountered were with the bearings that kept the long shaft properly lined up. It was during April 1895 that the generators were first turned over by the water wheels. It required some time to get the difficulties with the bearings straightened out. Then came a period of test for the generators and water wheels, so that it was not until August 1895 that we were ready to begin commercial operations. There is one incident connected with the start of the first commercial plant that will bear repeating, for it emphasizes a moral.

The plant of the Pittsburgh Reduction Company, now the Aluminum Company of America, manufacturers of aluminum, was to be the first started. The plant consisted of some rotary-converters whose function was to convert the alternating-current received from the power company into the direct-current that was necessary for use in the aluminum process. So far as we could tell, everything was finally ready for starting at both the main and auxiliary plants and August 26th, 1895 was set as the day for starting. Much against the wishes of the engineers no rehearsal start was permitted; the switches were to be thrown on August 26th and things were expected to start. The morning of the 26th came and in the presence of quite a delegation of officers of the power company, the switches were closed. Instead of starting up, however, the rotary converters simply stood still and rumbled. An investigation presently showed that by an error two of the cables, coming from the power house half a mile away, were interchanged so that the "phases" were crossed. It was an error that had no significance, and the remarkable thing was that this was the only thing that was found to prevent starting on time. However, the disappointment of the company's officers that had assembled to see the start was very keen, far and entirely out of proportion to its insignificant cause. In this case, after a few hours work to find and remedy the trouble, the start was made without further difficulty. The moral is evident. Don't advertise to start a plant of this kind

until you are sure that every one of the almost numberless details is ready to do its share of the work. The only way to be sure of this is by a rehearsal that takes place in the bosom of the family.

It takes all kinds of people to make a world. That old saying was never better illustrated than by the people that visited the power plant. The ludicrous questions that were asked would fill volumes. One man asked what make of pump was used to pump the water from the wheel pit. Another was surprised to see the water going into the pen-stocks leading to the turbines instead of coming out. They both probably had some vague idea that we had to pump out water after it had passed through the turbines. "Oh, then you don't use the falls; you just use the river as a source of water supply," and "why can't we have a similar development at Detroit? We have as great a water supply as you have here;" these are only samples of remarks that were continually being made. Usually it was easy to convince such doubters that the fall was a necessary part of our development scheme and that the idea of pumping the water out of the wheel pit was equivalent to trying to lift one's-self over the fence by his boot-straps.

Another man's question would be "where is your big wheel?" I have often felt that I would like to put myself into that man's place and see for myself the picture that he had made for himself of our plant. Probably he expected to see a huge breast wheel set up against the falls themselves and perhaps connected to machinery by belt or chain or gear. And apropos of this suggestion another man asked how we kept our big belt dry. Questioning developed that his idea of our development was that the power, obtained in some mysterious manner from the falls, was transmitted through the tunnel by belt to the electrical machinery in the power house. He had heard of our power plant for generating electricity and of the tunnel as a part of the scheme. His imagination had supplied a belt connection through this tunnel and the greatest difficulty he saw was the slipping of the belt on account of water.

On one occasion a party of visitors was being conducted through just after a priming coat of red paint had been applied to some of the pen-stocks. The group was looking

down into the wheel pit when one of the party exclaimed to an accompanying lady, evidently his wife, "There, you can get some idea of the enormous energy developed; see, that big pipe has become red-hot with it." And it was said in a way which would indicate that he was in earnest. The lady wondered that it was so cool in the pit in spite of the red-hot pipes.

One enthusiastic visitor exclaimed, as he looked down the line of ten whirling generators; "and is it possible that these dynamos supply all the light of Niagara Falls?" Another asked how many volts were generated in a day; another, on hearing some general explanation on the output of the plant, asked where the kilowatts were kept and if he could have one to take away as a souvenir. Still another wanted to see our collection of diamonds. Questioning developed that he had heard something about the early work of Acheson who discovered carborundum while trying to make diamonds. As usual this visitor's ideas were considerably garbled and he thought that most of our power was used in making diamonds and that we had a magnificent collection on exhibition. Another man standing at the top of the wheel pit saw some water-spray thrown through a crack at the bottom; "Is that your liquid air escaping," he asked. On several occasions I have opened the trap-door over a running wheel to show the chaos of water as it leaves the turbines and have had to restrain members of the party from starting down the ladder into it. They evidently thought it was the next place to go and were not to be daunted by a little water.

Niagara is, and always has been, a mecca for the tourist. Not all of them are of the same stripe as indicated by the foregoing incidents. Distinguished men of all walks of life and of all nations were continually going and coming. Not a small part of the interest in being attached to such a plant was the opportunity thus afforded to meet and talk to the well-known men who were continually visiting the plant. One of the earliest distinguished visitors to the plant was Le Hung Chang, the Chinese Statesman. Four Chinese bearers carried him about seated in his sedan chair. He showed due Chinese politeness by asking numberless questions about the things he saw. It was then that occurred

the incident of the cane that was considerably advertised by the newspapers on the following morning. The space between the brick switch-board structure and the generators opposite it is somewhat limited, perhaps eight or ten feet. The sedan chair was borne through this passage and its occupant was thus brought near enough one of the generators to reach it with the cane he carried. While passing he reached out with the cane and made several jabs at the rapidly revolving generator. The extruding bolt heads caught the cane and wrenched it from his grasp. The place was full of reporters at the time and the incident was made much of, much more than it deserved. His object in making the move was evidently to find out at first hand something of the nature of the objects he was seeing. No damage whatever was done either to the machine or to the visitor.

Another famous Chinaman whose visit left a vivid recollection in my mind was Wu Ting Fang, formerly Chinese Minister to the U. S. He also showed true Chinese politeness by asking innumerable questions, questions too that showed a keen appreciation of what he saw. Nor did he restrict his questions simply to what he saw. A prominent engineer from Buffalo was a member of the party and both he and I were kept busy furnishing facts and figures in reply to the rapid fire of questions. Finally Wu detected a discrepancy between certain items of information that we had given him on the same subject. Instead of asking which of us was correct or maintaining silence his question was, "Which of you two is the abler engineer?" Since we were sitting at the time one on either side of him the question was somewhat embarrassing.

Nikola Tesla visited the plant for the first time in January 1897. One incident will always make me remember his visit. In his tour around the plant his eye caught a small motor used in starting a rotary converter. "What is that," he asked. The machine indicated was a Tesla motor. Surely "it is a wise father that knows his own child."

In 1901 Thomas A. Edison visited the plant for the first time. During his tour of inspection he remarked that he "didn't know very much about alternating current" and then

proceeded to ask a string of questions so worded as to make it quite impossible to believe his statement.

President McKinley visited the plant just an hour or two before he was shot. On leaving the power house he went straight to the train that took him to the Pan American Exposition at Buffalo, where he was the chief figure at the fatal reception in Music Hall. His last signature was written in the visitor's register that has always been kept at the power house.

Lord Kelvin visited the plant at least twice and always took a keen interest in its development. Prince Hilkoﬀ the Russian Minister of Railways was another interested visitor. Prince Henry of Prussia made the inspection of the power plant a part of his tour of the United States. His official host was "Fighting Bob Evans." Among others whose names occur to me are Theodore Roosevelt (while governor of New York), Admiral Sampson, General Joe Wheeler, Andrew Carnegie, J. P. Morgan, Duke of Marlborough. These are only a small fraction of the names that could be given of men known to fame who have been attracted to Niagara by the double magnet of the world's greatest artificial wonder situated alongside of the world's greatest natural wonder. It is no small privilege to have been so situated as to come into contact with such men.

I find that the impression is more or less prevalent that the Niagara power plant has had more than its share of troubles. That there have been minor difficulties no one will deny, but that there have been more than might reasonably have been expected, taking into consideration the character of the plant and the magnitude and newness of some of the problems encountered, is emphatically not true. The record of this plant for continuity of service both on the local and on the long distance loads is such as to uphold this statement.

The real criterion too of a plant's success, at least from an engineering standpoint, is this ability to give continuous service. Some accidents have happened, of course, but recovery from their effects has always been rapid. Then too an accident to the Niagara plant is always advertised more widely than in another plant on account of its prominence. Another disadvantage in this respect is the fact that con-

tinuous service at the Niagara plant means service for every minute of the 24 hours of every day in the year. This condition is due to the peculiar demand of the industries at Niagara. Continuous service in the ordinary lighting plant means continuous service during the lighting hours only. That is, a lighting plant has to keep "tuned up" only during five or six hours of the day. Niagara has to keep "tuned up" every hour of the day. Similarly a railway plant has a respite during the early morning hours, a chance to tie up any loose ends that may have developed during the day. At Niagara the falling off during this period is comparatively a small percentage of its total load. In spite of these handicaps Niagara's record for continuity of service is one to be proud of.

In looking back over one's experiences in such a plant it is natural that the mishaps, the accidents, the mistakes, should be the things that catch the eye rather than the record for good performance. They are the high spots that one's memory naturally bumps against as it travels over the past. Therefore I hope that it will not be taken as a record of normal operation if I jot down a few of these same high spots.

Short-circuits are among the things that have to be expected from time to time in any electrical plant. Niagara was no exception. It was early noticed, however, that these short-circuits were more violent, gave evidence of a greater amount of current in the short-circuits than had been anticipated. The first Niagara generators were designed with a poor regulation. It was expected that this would have the effect of limiting to a large extent the current that would flow on short-circuit. After a few had occurred, however, evidences were noted of currents far in excess of the perhaps double full-load current that might be expected.

On several occasions cables were thrown from the brackets to the floor by the magnetic repulsion that would take place between the out-going and return cable at the instant of short-circuit. One such short-circuit involved the whole length of the cables running to the Pittsburgh Reduction Co. For a distance of about 2000 feet these cables were carried in a tunnel, about three feet wide and five feet high on either side of which were placed about four tiers of

brackets, each bracket capable of carrying four cables. The distance between the inside ends of these brackets was approximately two feet. The four cables to the Pittsburgh Reduction Co. were of 950,000 c.m., about one and one-half inches in diameter over all, and weighed, including lead-covering, approximately five pounds per foot. They were carried on one of the above tiers of brackets. A heavy short occurred at Pittsburgh Reduction Co's. end of these cables. After the short the outside cable throughout the whole 2000 feet of its length in the tunnel was found on the next lower tier of brackets on the opposite side of the tunnel and the job was almost as neatly done as if a gang of men had made it their special business.

On another occasion, a short at a time when six machines were running in parallel gave a repulsion on a section of the bus bar so great as to leave it bent out of its former straight line about three or four inches. At this point the bus bar consisted of a solid copper rod one inch in diameter and the supports were only five feet apart. The bar of opposite polarity was twenty-four inches away. It would take a powerful blow from a heavy sledge-hammer to produce the same result mechanically. The amount of current necessary to produce this repulsion under these conditions must have been some where between 100,000 and 200,000 amperes. If this were equally divided among the six generators each would have to supply from 20 to 40 times the normal full-load current.

Nor did all the repulsion effects occur on the outside circuits. The repulsion effect on the windings of the armature was even more severe than that on the circuits outside the armature, and presented a far more difficult problem. The distortion of the armature windings due to the heavy repulsion effects was sufficient to cause considerable damage to the insulation. In these machines this effect of electromagnetic repulsion in armature windings became, for the first time, a factor to be reckoned with.

Today, no designer thinks of laying out a large machine without carefully considering the matter of proper bracing in the armature winding. In a large machine there is a considerable amount of energy existing as magnetic flux set up by the field. Under a condition of short-circuit, this en-

ergy is practically zero. At the instant of short-circuit, this stored magnetic energy tends to escape with the utmost rapidity and it is this sudden escape of the magnetic energy that causes the enormous currents whose effects are above described. After a short-circuit is once fully established, the amount of current from the armature may be easily calculated from the machine constants; while being established however, the amount of current is enormously greater than obtains in the stable condition. It was in these Niagara machines that this effect became for the first time a noticeable factor. It was not a very difficult task in this case to devise a bracing that was ample to take care of the strains but it merely shows one of the new problems that was raised by the Niagara plant.

Another effect astonishing by its magnitude, is the tremendous heat that is liberated during short-circuit condition. On the occasion of the short-circuit of six paralleled machines mentioned above, the reaction of the armature back on the fields was so great as to trip all the field breakers although they were set for at least double normal current. The duration of the short was therefore very small, probably not more than one second. Nevertheless the heat was sufficient to scorch to some little depth the head of a wooden reel that stood about ten feet away, set fire to a bunch of waste twelve feet distant and blister paint eighteen feet distant. On another occasion a short that lasted only five to ten seconds melted out sections of several million c.m. cables that lay close together, the sections being from two to eight feet long. The energy that it is possible thus to turn loose in an extremely small space of time must be seen to be appreciated.

The first Buffalo transmission line was installed in 1896 and started operation in November of that year. At the time of its installation it was one of the longest, and contemplated the delivery of by far the largest amount of power of any in existence. While this line has always been highly successful, the casual recollections that I have of its operation are naturally recollections of the accidents that occasionally happened to it.

I find, through questions put to me occasionally, that there is a popular impression more or less general that some

of the accidents to the Buffalo line were caused by cats, and some have actually gone so far as to ask for an explanation as to exactly "why the electricity in a cat's fur should be so antagonistic to that in a dynamo?" There is the barest germ of truth in these cat stories, in that two shut-downs of the Buffalo line were caused by those animals. There was a considerable number of rats in and about the plant and a few cats were kept for their benefit. One night a short occurred on the Buffalo for which no reason could be assigned until the body of one of these cats, burnt almost to a cinder, was found between one of the high-tension choke coil terminals and ground. On another occasion a cat climbed one of the transmission poles some ten or fifteen miles from the Niagara end and in some manner got its body between two of the conductors although they were at this point 24 inches apart. A short-circuit resulted causing a brief shut-down of the line. Signs of an arc on the transmission conductors and the cat's burned body on the ground underneath, were, in our minds, sufficient evidence to convict the cat. The newspaper men got hold of this last incident and the fame thereof spread abroad, evidently growing as it spread; for some six months later someone sent me a clipping from an English paper published in Hong Kong describing an accident to the Niagara transmission line due to a cat which resulted in depriving the whole of western New York of power for hours.

On the Niagara line, as has also been noted on almost all other lines, a defective insulator would often set fire to the top of the pole, usually at the point where it is joined by the cross-arm. On one occasion this happened to one of our poles that stood near a farmer's house. Upon seeing the burning pole the farmer secured a small pail of water, climbed the pole and put out the fire. Just how he escaped getting killed in the operation is more than I have ever been able to understand.

The right of way of the transmission line was entirely cleared of trees very shortly after starting the line. During the progress of this work a peculiar accident happened. A rather crooked branch free of small limbs lay on the ground near where the woodmen were felling a tree. When the tree fell it struck one end of this crooked branch in such

a manner as to throw it high into the air. Falling, the branch lodged in among the transmission conductors and stayed there. Although the transmission cables were of 350,000 c.m. (practically three quarters of an inch diameter) in about ten seconds two of them burned entirely in two and fell to the ground. The branch in this case was somewhat green and therefore sufficient of a conductor to keep the energy of the partial short-circuit concentrated at the point of contact.

Arcs have formed on transmission conductors quite frequently but unless there is something to concentrate its force it does no damage to the conductors. The above is the only instance I recall where the copper line was burned apart. On another occasion the 500,000 c.m. aluminum line burned in two just under the edge of a metal hood that protected it where it entered the transformer house. In this case it seems probable that a lightning discharge jumped across (about fifteen inches) and the dynamo current followed, and the arc was directed by the overhanging metal hood to approximately the same spot until the cable parted. In this ability to withstand the action of arcs, it is well-known that aluminum is inferior to copper. The above, however, is the only case to my knowledge where the aluminum line at Niagara parted due to an arc.

So far as I am aware, it was at Niagara that for the first time was noted the excessive rush of current that often takes place in a transformer when first thrown on a line. A rotary converter supplied by the General Electric Co. was arranged to start from the d-c. end. In order to prevent the shunting effect of the transformers it was arranged that the a-c. brushes were to be raised on starting and placed in contact with the collector rings again after full-speed had been reached. It was noted that sometimes on putting down the brushes, signs of an excessive current were noted, a flash at the point of contact, and burning of the ring and brushes. An ammeter was put in circuit of ample capacity to read the magnetizing current of these transformers and almost at the first trial its needle received so violent an impulse as to twist it around the end stop. Further experiment showed that the first rush of current might, under some conditions, amount to many times the full load of the trans-

former. The phenomenon is due to the fact that a transformer on being disconnected from the circuit may still have a very high "magnetic set". The magnetic circuit being an entirely closed one, a slight residual magnetic force leaves a large residual magnetic flux. On being reconnected to the circuit, if the first impulse of current tends to cause a magnetic flux in the same direction as the residual, evidently the iron is forced far beyond the saturation point and in consequence an excessively large momentary magnetizing current is taken. This condition is one which corrects itself rapidly and entirely disappears after a few alternations. It is also a condition which does not appear every time the transformer is connected to the line, since the effect depends upon the point of the voltage wave at which the transformer is disconnected as well as that at which it is reconnected.

The large Buffalo transmission transformers showed this effect to a large degree. Sometimes the closing of their switches would show no effect whatever and at others there would be a tremendous jar and shock as if they had been struck with a huge sledge-hammer. That there was a considerable mechanical shock on these occasions was shown by the fact that great clouds of dust inside the transformer would be loosened up whenever it occurred. This effect is one which is the more noticeable on low frequency transformers, since it requires the iron to be worked fairly well up towards magnetic saturation, as is the case in low frequency transformers only.

Another incident noted in connection with these transformers is possibly worth repeating. On a number of occasions it was reported that upon throwing in the transformers, sparks and other indications of danger were seen. On at least one occasion the transformers were pulled off the circuit with the full expectation of finding them burned out. However, rigid tests were applied without finding the slightest indication of trouble. By observation the cause was finally determined. When throwing on the transformers under some conditions the change in magnetic flux is very rapid during the first instant of connection. The laminated iron of the transformer itself forms a secondary in which a voltage is generated. Under normal conditions

there is ample insulation between these laminae to prevent a current flowing, but under the excessive strain that sometimes occurs at the instant of connection, this partially insulated circuit breaks down, thereby giving rise to the effect noted. After one knows all these things they seem perfectly simple and natural, but before that they are sources of much anxiety.

The primary object of this paper has been simply an account of some of the more interesting events that happened at the Niagara plant during my sojourn there. These are simply a few of the incidents of operation that one is sure to get in such a plant. It is the integration of such items that makes experience.

REVIEW OF SAFETY WORK OF THE A.I. & S.E.E.

By W. T. SNYDER

We are certainly pleased to see the large attendance here this evening. We regret very much to announce that Mr. L. H. Burnett could not take his part on the programme this evening on account of illness, and he asked me to express to you his sincere regret at not being able to be here.

The subject that we have chosen for our meeting this evening is one that this Association has been active in ever since its beginning; in fact the Association of Iron & Steel Electrical Engineers was among the first in the field of organized safety work in the Iron and Steel Industry. We have the distinction of having been instrumental in launching, at our Milwaukee convention in 1912, what is now the National Safety Council.

I have here a resolution that I tore out of the Proceedings of that Safety Congress. In 1912, there was held what was termed the first Co-operative Safety Congress. In connection with the Convention of our Association, there was called together through the efforts of our Safety Committee, the men who were at the head of safety and welfare work of the industries of the country, the transportation systems, etc., and from the gathering—that co-operative safety congress—was started, as I said, the National Safety Council. That is something that very few of the guests, probably, are aware of, and, no doubt, a number of our members have forgotten it; so I will read this resolution that was adopted by our Association:

“WHEREAS, The Association of Iron & Steel Electrical Engineers regarding as worthy of particular attention the hazards to life involved in electrical operations in steel mills, and appreciating the importance of the General Safety Movement not only in electrical en-

gineering, but also in the steel industry as a whole, and in all the other varied and important industries of our country, and having met with such prompt co-operation in their proposals to establish a National Organization devoted to securing increased safety to human life, have reached the conclusion that such an organization can best be brought about by action at this joint meeting of the Association of Iron & Steel Electrical Engineers and the Co-operative Safety Congress, and it is therefore hereby

RESOLVED, That the President of the Association of Iron & Steel Electrical Engineers be requested to take the first steps towards the formation of a National Organization for the promotion of safety to human life by appointing a Committee on Permanent Organization, which shall contain representatives of the Federal and State Agencies already established to supervise conditions of safety in our industries, and shall also contain representatives from the Mining, Transportation and Manufacturing Industries of the United States, and be it further

RESOLVED, That the committee so appointed shall be and is hereby authorized by this Congress to organize and create a permanent body devoted to the promotion of safety to human life in the industries of the United States; this Committee to have authority to call future Congresses of safety, increase its membership if it so desires, and to do such other acts as will promote the object for which it is established.

The following Committee was appointed:

Dr. Chas. P. Neill, U. S. Commissioner of Labor.
Dr. Joseph A. Holmes, Director Bureau of Mines.
Chas. C. McChord, Interstate Commerce Commission.
Mr. F. W. Houk, Commissioner of Labor, Minnesota.
Dr. H. M. Wilson, Bureau of Mines.
Dr. L. W. Chaney, Department of Commerce and Labor.
C. W. Price, Wisconsin Industrial Commission.
Dr. M. J. Shields, National Red Cross.
Mr. James T. McCleary, Iron & Steel Institute.
Mr. John Kirby, Jr., National Association of Manufacturers.
Mr. R. C. Richards, Chicago and Northwestern Railway.
C. L. Close, U. S. Steel Corporation Safety Committee.
F. C. Schwedtmann, National Association of Manufacturers.
David Van Schaack, Aetna Life Insurance Company.
Mr. R. J. Young, Illinois Steel Company.
Mr. L. R. Palmer, Association of Iron & Steel Electrical Engrs."

Our sessions were conducted in one room and this National Safety Congress was carried on at the same time in an adjoining room, holding sessions under various auspices during the week, viz.; Mines, Transportation, and Manufacturing sessions, and a joint session with the Iron & Steel

Electrical Engineers. In order to show their appreciation of the work of the Association of Iron & Steel Electrical Engineers, the following was communicated to this Association by the chairman of the above committee:

"To the Association of Iron & Steel Electrical Engineers:

It is appropriate before final adjournment of the Congress, which was made possible by your initiative and has been made successful by your energy, to make a formal statement of the results of the deliberations of the committee requested by you to undertake the further development of the idea.

Your committee has carefully discussed the situation which confronts the movement. After this consideration, conclusions were reached which may be stated as follows:

1st. That a new organization along lines similar to existing organizations which make the subject of safety in industry a part of their program is inexpedient.

2nd. There is need and opportunity for a co-ordinating body which shall serve for future congresses and safety exhibits, the same function which the electrical engineers have served in the present case.

3rd. That your committee will undertake to act as such a National Council for Industrial Safety, adding to their number from time to time representatives of such other bodies as concern themselves with its problems.

4th. That the National Council will begin at once to formulate plans for a 1913 Congress.

5th. That consideration shall at once be given to the promotion of an International Congress on Industrial Safety, at the Panama Canal Exposition in 1915. As the first step in carrying out the conclusions stated above, the Council has organized by electing the following officers: Chairman, Ferd C. Schwedtman, National Association of Manufacturers; Vice Chairman, Lew R. Palmer, Iron & Steel Electrical Engineers; Acting Secretary, Lucian W. Chaney, U. S. Bureau of Labor.

Finally the newly constituted body directed that there be placed on record its great appreciation of the services rendered by the Association of Iron & Steel Electrical Engineers, both in promoting the present congress, and to the general cause of industrial safety.

Lucian W. Chaney,

Chairman."

In order to show that they still have a feeling of gratitude towards our Association, the National Safety Council at its Fourth Annual Congress in Philadelphia, last October, passed a resolution electing to honorary membership in their body, our Association, in recognition of the services rendered in launching their organization. The following letter, from

the National Safety Council, was addressed to our president, O. R. Jones:

"I now take pleasure in giving you this formal notice that at the Annual Meeting of Members of the National Safety Council, held at Philadelphia, October 19, 1915, your Association was elected to Honorary Membership in the National Safety Council. This action was taken, we believe, as an expression of appreciation of the invaluable services of your Association to the Safety Cause, and as a recognition, in a measure, of the debt the Council owes to your Association for its present existence.

We all look upon your Association as the "father and mother" of the work being conducted by the National Safety Council.

With kindest regards and best wishes for the continued success of your Association's work, I remain,

Sincerely yours,

W. H. Cameron,

Secretary."

The National Safety Council is now composed of more than twenty local councils in the principal cities of the United States. Its influence is felt in practically all of the industries, and I was just informed by Mr. Palmer that the membership of the National Safety Council represents almost ten million workmen.

THE USE OF CENTRAL STATION POWER SERVICE IN STEEL MILLS

By JOS. MCKINLEY

The past few years have shown a great increase in the use of electric power in steel mills, and a rapid development in the Central Stations of the country.

Statistics show that in the Iron and Steel Industry there was in use in 1904 primary power in the amount of 2,422,577 h.p., and in 1914 this had increased to 4,120,000 h.p; an increase of 70%. During the same period, the horse power in electric motors in the same industry had increased from 306,868, to 1,540,000; an increase of 400%. That is to say, in 1904, 12.7% of the total horse power in the industry was in electric motors, and in 1914, 37.5% of the total horse power was in electric motors. During the ten year period from 1902 to 1912, the Central Station plant rating had increased from 3,000,000 horse power to 11,000,000 horse power; an increase of 266%.

The increase in the use of motor drive in the steel mills is due to the use of machinery for handling materials, such as hoists, cranes and haulage in the operation of which machinery motor drive had a great advantage in economy of power transmission and control, and also in the displacement of the steam prime-movers in the operation of the various types of rolling mills due to many advantages, among which may be mentioned:

Low maintenance costs.

Superior speed regulations.

Greater tonnage output and better quality of output.

Economy in power.

Economy in power transmission.

Saving due to less interruption.

Ease of control.

Safety.

The advancement of the Central Station comes from the development of large prime-movers, which, together with the improvements in transmission and distribution, have made it possible to serve much greater areas, securing for it the greater economies in production which comes in serving diversified industries. Much thought and study has been given to the matter of inter-connection of large Central Station Systems. Such an arrangement shows still further possibilities in lowering the cost of producing electrical energy and obtaining for the community the economic advantages of securing a service with minimum outlay of capital, and preservation of natural resources due to saving in fuel, copper, etc.

Coincident with the remarkable growth and constantly decreasing cost of production by the Central Station in the past ten years, has been the improvement in it's service, it's continuity and regulation. Knowledge of these facts and it's future possibilities along the same line have naturally interested the Iron and Steel Industries in the use of this service.

The fact that motor drive in Steel Mills has decided advantages over any other form of drive, we believe to be well established. The decision for it's general adoption will depend entirely on the costs obtaining.

In the consideration of the Central Station power, the question is essentially one of cost.

The Central Station organization has three distinct functions to perform, i. e: generation, distribution, and sale of electrical energy. Before getting into discussion of these three questions, it will be well to define the terms "Load Factor" and "Diversity Factor", as used in this paper.

Load factor is defined in several different ways, but its general significance is the same in all cases. It is a measure of the ratio of the average consumption of an installation to the maximum. The average is usually taken to be the total energy in kilowatt hours, divided by the time of operation, while there are several ways of fixing the maximum. It may be taken as the sum of the ratings of the apparatus connected to the line, or it may be determined by the maxi-

mum load sustained for a given period of time, as shown on the recording wattmeter. The latter is the method in most general use, and the one adopted in this paper. The operating time is taken as 8,760 hours per year.

Example illustrating method of determining Load Factor: A maximum sustained load of 1,000 kilowatts is shown by a recording wattmeter placed in a certain installation, and the kilowatt hours as measured by kilowatt-hour meter found to be 2,628,000 for a period of one year. The load factor of this installation is 2,628,000 divided by $8760 \times 1,000 = 30\%$.

Diversity factor of a power station is the quotient obtained by dividing the sum of the individual maximum demands of the installation served by the station by the maximum demand of the power station. To illustrate, let us suppose that a power station has a maximum demand of 800 kilowatts as shown by a recording wattmeter, and that it supplies four consumers having maximum demands of 100 kilowatts, 200 kilowatts, 300 kilowatts and 400 kilowatts respectively. Then the diversity factor is 100 plus 200 plus 300 plus 400, divided by 800, or equals 125%.

Load factor affects both the fixed and the operating charges per kilowatt-hour output of the station. The higher the load factor, or the greater the kilowatt-hour output, the less is the fixed charge per kilowatt-hour output. The operating charges are affected by the load factor, for the reason that the higher load factor, the higher the average load, hence greater efficiency of plant.

Increasing the diversity factor, it is seen, obtains for the Central Station a lower required station capacity per kilowatt of installation served, hence reduces the fixed charges per kilowatt served. Its increase also will mean an increase in the load factor of the station. To illustrate the possibilities of improving the stations diversity factor, I might quote some figures compiled by Mr. Insul, of the Commonwealth Edison Company of Chicago: "If the railroads in Chicago districts should be electrified, they would add 125,000 kilowatts to the present load, and that one system would be obliged to carry 728,000 kilowatts if no account were taken of the diversity factor. Owing to the over-lapping peaks, however, the service could be rendered

by 577,000 kilowatts, making a saving of 150,000 kilowatts by centralization. This represents a capital saving of \$30,000,000.00, and the saving in fuel consumption of 5,900,000 tons, or a total of 11,000,000 tons."

The power station is located in that section of the territory where fuel and water supply are obtained at least cost. This will permit of using comparatively low priced property. It is also to be noted that the square foot of space required is much less per kilowatt of installed capacity than that required for a smaller size of equipment; so that for property and buildings the investment is quite small.

Let us consider a 100,000 kilowatt plant, 20% of which is held in reserve, having a system diversity factor of 1.5. This plant maintains 100,000 kilowatt capacity for supplying 120,000 kilowatts of consumers demand, or .833 of a kilowatt for each kilowatt of consumers demand. Now let us consider a steel mill whose requirements are 3,000 kilowatts, 50% reserve would be conservatively provided, and total capacity would be 4,500 kilowatts—say three 1,500 kilowatt units. This would mean 1.5 kilowatt installed per kilowatt required. It is thus seen that the Central Station would be required to hold for this 3,000 kilowatt of demand mentioned, $3,000 \times .833 = 2,499$ kilowatts and assuming the Central Station total cost per kilowatt of capacity to be sixty-five (\$65.00) dollars, then its power plant investment to take care of the customer would be 2,499 times \$65.00, or \$160,225.00; while the customer's outlay would have been, on the basis of Eighty-five (\$85.00) dollars per kilowatt, 4,500 times \$85.00, or \$382,500.00.

Assuming the rate chargeable as overhead to be the same, then the fixed charges per kilowatt hour of the consumer would be 2.38 times that of the Central Station.

The operating costs of the large Central Stations also show to great advantage as compared with the smaller plant. On the basis of the smaller plant operating on 50% load factor and the larger on 65% load factor, the water rates would compare approximately at 17 to 13, or about a saving of 30% for the larger units. The other items comprising the operating costs greatly favor the larger capacity plants.

We have attempted to show in the above that generation costs of the large Central Station are already much low-

er than that possible to obtain in small plants, such as would be required in the average steel mill. By increasing its size, taking on more consumers of a diversified nature, and improving of load factor, these costs must continue to go down.

The transmission of the energy by the Central Station from its power plant to its consumers to introduce a cost which the isolated plant does not have. It is also this link in the Central Station's system which in the past has been looked upon by many consumers as a very likely place to develop serious trouble. Transmission costs will be affected by load factor and diversity factor much the same way as the generating costs. The distance energy is transmitted will also vary the cost. Serious commercial difficulties prohibit adopting any arrangement which would take distance into account in rates. Of course, no company is obliged to extend its lines such a distance, and through an unproductive district, as would make the delivery of current, at the rates prevailing, unprofitable. In such case it is possible to arrange for such consumers to build their own lines under the supervision of the company, and in the event of revenue derived from those supplied from this line reaching a determined amount, then the line is taken over by the Central Station.

Great improvements have been made in transmission apparatus and material, which enables us to transmit economically, and supply at high voltages large amounts of power.

Consumers are now connected to transmission lines and distributing lines. Precautions must be taken in case of consumers connected to the transmission line. Attendants, skilled in the handling of high tension switching apparatus, are required and all apparatus must be kept under close inspection in order to arrest outages of the system.

Large and important installations are connected to a so-called ring feed system, or have two separate circuits installed. The ring feed may be used where a customer is located on a transmission line connecting two sources of power. In this arrangement the line is looped into the consumer and permits his taking power from either end of the line. In case of use of two circuits, double throw switches

are provided, so that in case of trouble on one line, the load can be thrown over to the other.

By such methods and the use of high-grade line construction, with proper protective apparatus, transmission interruptions are reduced to a negligible quantity.

The sale of Central Station service is by contract. Public Service Commission exists in practically every state of the Union and all companies are subject to regulation by the Commission of its State. Rates available for service, and all provisions in contracts, are set forth in various schedules which comprise the issuing of company's tariff book—much after the tariff books of railroads. The principal features of the contracts are the rates, the capacity contracted for, the term of contract, and the kind of service. These are clearly set forth. Contracts may be made for periods of years, during which term the customer is insured against increased rates, but can take advantage of any subsequent schedule filed by the company which would effect a reduction in his rates.

Practically all schedules for sale of power are on a two base principle. That is to say, they are made up of a fixed charge, determined by the amount of the customers maximum demand, and an energy charge for the kilowatt hours consumed. This type of schedule effects a lower rate for the consumer the higher his load factor reaches. Constant study and analysis of the power of all industries in the community served are essential. The selling policy must at all times be such as to encourage the use of its service. Constant effort is made to secure as customers those installations which will increase the company's volume of business and improve its load factor. The success of the sales department along this line will enable the company to reduce its cost of producing energy.

The average steel mill load is about 3,000 kilowatts, having an average load factor of about 50%. About the only way this differs from the conditions of the smaller industrial plant is that the peak loads are somewhat higher in proportion than the loads of the small industrial plants. The cost of producing the power in steel mills runs along practically the same lines as that of the smaller industrial plants.

The fact that the load is characterized by extreme peaks would indicate that this load can be handled more economically by the Central Station with its larger units, than by the comparatively small units in use in the steel mills.

Conclusions

1. The Central Station's position in the field of industry is permanent. Its sole business is the manufacture and the sale of electric current. Its business is conducted on a large scale and enables it to adopt methods of refinement for improved efficiency and service which would be impractical in small plants.

2. Unless the fuel is a by-product, the industrial plant cannot compete with the Central Station.

3. The manufacture of electrical energy being the sole business of the Central Station, its costs are accurately determined.

4. The use of Central Station Service eliminates the investment of capital in land and building from which there is no direct production.

5. The Central Station can maintain better voltage regulations, and, on account of size of units and the diversity of their load, can absorb high peaks.

6. The Central Station can supply increased power requirements at lower rates, where the reverse is usually the case of the small isolated plants.

7. The use of the Central Station insures the cost of the customer's power. The cost of power supplied by isolated plants will vary with the price of fuel and the character of maintenance provided.

8. The use of Central Station power permits space to be used for productive purposes, which would otherwise be required for power house.

9. It reduces the cost of administration.

10. It reduces the cost of reliability insurance.

11. It eliminates the smoke nuisance.

12. It provides for a continuous supply of power at all times.

DISCUSSION

W. T. Snyder: Following the plan decided upon at the beginning of this year of having the monthly meetings in Pittsburgh under the auspices of the different special committees, the meeting this evening is under the auspices of the Central Station Power Committee, and will be conducted by the Chairman of that Committee, Mr. Clark S. Lankton.

C. S. Lankton: We are about to consider a new but vital phase of Steel Mill electrical engineering. We have heard rumors that the Central Station, because of its tremendous growth and its high efficiency, has reached a position where we can not operate our power plants to an advantage, but must discard them and buy electric power from a central station. Is this a fact? We want to know the truth about this matter.

To be competent Electrical Engineers, we must consider all propositions that might reduce the price of electric power, and, in turn, the cost of steel per ton; and thereby benefit our fellowmen by an extended use of this commodity. Mr. McKinley of the Duquesne Light Company has given us some light upon this subject from the central station's point of view, and we are grateful to him for his paper. He has given a great deal of information that we wanted. He has spoken about diversity factor, load factor, and a great many other terms that sometimes are confusing. We are also glad to learn of new developments. In the development of Central Stations, large turbine units have proved a main factor and Mr. Hodgkinson can probably give us a description of a 40,000 kw. unit now being installed in this district.

F. Hodgkinson: Following is a description of a 40,000-kw. turbine being built for Duquesne Light Company:

This turbine, one of the largest machines yet contemplated, is under construction at the works of the Westinghouse Machine Co., for the Brunots Island Power House of the Duquesne Light Co. The complete turbine comprises two separate turbine elements, each driving an independent generator and of a design similar to some 30,000 kw. tur-

bines that have been in operation for over a year in the 74th Street Power House of the Interborough Rapid Transit Co. This installation set a new mark for reliability on the one hand, and economy on the other. The turbines went into service without any interruptions and substantially continuous service has been available from all of these machines since that time. Very careful tests have been carried out showing an unprecedented steam consumption, all guarantees having been fulfilled.

The feature of construction of these machines is, as has been mentioned above, the carrying out of the steam expansion in two separate cylinders, each of which is considerably smaller than though the whole expansion were carried out in one cylinder, eliminating the engineering difficulties due to the size of a single structure, which difficulty would be greatly augmented by the greater temperature range which would exist in a single structure. The high pressure element expands steam from boiler pressure to about 14 pounds absolute, the low pressure element expanding the steam from the latter pressure to that of the condenser.

In the case of the Duquesne Light installation, with 40,000 kw. load, the work done by the generators will be equally divided. With loads higher than this, the proportion carried by the low pressure element will slightly predominate, while with lesser loads than 40,000 kw., the reverse would be the case.

Regulating mechanism is provided on the high pressure element only, the low pressure converting into useful energy all of the steam delivered to it from the high pressure turbine.

The high pressure turbine operates at a speed of 1800 r.p.m., and the speed of the low pressure is 1200 r.p.m.

I do not know that I am able to add very much to Mr. McKinley's remarks on the matter directly under discussion, namely, "whether steel works should buy their energy from central stations or employ a power plant of their own?" A good reason for that is that I have had no opportunity to consider which way we would sell the most turbines.

I would like to repeat a remark that I made on a previous occasion, that is, "you gentlemen that are engaged in the management of power plants in connection with steel

mills are principally concerned in producing the most steel for the least money in which the generation of electrical energy is but an incident. The powerhouse man, on the other hand, has no interest but to produce kilowatts for the least money. It therefore seems most natural that those interested in steel mills should look to the powerhouse man for the latest thoughts on design of powerhouses."

Engineering Associations of those engaged in the management of large powerhouses, holding conventions at intervals, generally have a committee to submit to them a report on progress of main power generating units. The trend of evolution of these different reports is interesting. Years ago they discussed turbine economies, test records, etc., and features of detail design. As time went along the condenser came to be included and the other auxiliaries of the powerhouse until lately the turbine is hardly referred to, but much is said concerning the auxiliaries, particularly with reference to the utilization of their exhaust steam and means of arranging for a heat balance to insure hot feed at all times without waste of auxiliary exhaust steam at any time. There are many means of accomplishing this which would be out of place to discuss here. It is indeed quite natural that the trend of thought should be as described, because nowadays steam turbines of large capacity will convert 76% of the theoretical energy of the expanding steam into energy at the switchboard, and, plainly, there is not much more than this to be realized, and we must look to other means than improvement in the main power units if further economies are to be realized. I have already referred to one such possibility. Further development of the economizer is probable, particularly in admitting water to it at lower temperatures with consequent lower flue gas temperatures.

If you look back at the progress of turbines during twelve years, steam consumptions have gained—taking rough figures—from 20 to 12 lbs. per kw-hr., but this is by no means all that has been accomplished. Power unit costs, with the advent of the turbine, dropped from \$120.00 to \$30.00 per kw. Some large Corliss engine units, I believe, cost the former figure. Turbine-generator costs have now reached a level of less than \$10.00 for large sized units. It is plain from the above, therefore, that the turbine has

about reached the limit in economy, both in steam consumption and fixed charges. Of course the larger the machine the better is the economy, but in units of greater than 30,000 kw. the gain from this cause is slight, so improvement in the boiler house management and the more careful handling of auxiliaries, or at all events things extraneous to the main turbine unit, must be looked to as the source of further improvement.

I do not think there is any doubt but that the next move in this direction will be by means of high steam pressures, and I venture the prophecy that within two or three years, powerhouses will be under construction with their boilers arranged to operate with 600 lbs. steam pressure.

A study of the theoretical possibilities of operating such pressures is somewhat startling. If we put the same B. t. u.'s into steam generated at 600 lbs. as is required for 200 lbs. pressure and 200° superheat, which latter condition is about the maximum operating condition as to pressures and temperatures, regularly employed today, we will have steam at 600 lbs. pressure, superheated about 130°. It will be found that in expanding this steam adiabatically to an absolute pressure of one half pound per square inch, there is theoretically 13.6% more energy to be obtained. This, without any increase of heat content in the initial steam.

Of course the turbine is not going to avail itself of all this 13%. In the first place the fluid friction throughout the turbine will be greater because on one hand of the increased density of the medium in which operate the high pressure elements and on the other there will be a greater precipitation of moisture throughout the expansion through the low pressure elements. The exhaust will contain in a theoretically perfect engine 25% of moisture and in practice about 15%. In the second place, the high pressure turbine elements will not be as efficient because of the small steam volumes involved.

It is of course somewhat of a conjecture how much these losses will amount to. It is a fair assumption, however, that at least five or six per cent. betterment is to be secured by this means.

The natural question that follows is concerning the boilers, but no doubt boiler manufacturers will not lack the ini-

tiative, and it is not beyond bounds of possibility that the modern high pressure boiler will be of the flash type. Many of these are already built in small sizes and are said to be entirely satisfactory, automatically controlling the fuel supply by means of temperature rather than pressure. Consider a source of feed water supply several pounds higher than the pressure within the boiler discharging through orifices into a number of single tubular boiler elements exposed to the furnace gases. The water passing upwardly through the tubular element leaving as superheated steam. The material pressure drop between the feed-water supply and the interior of the boiler is necessary to insure water being fed equally to all the boiler elements.

R. L. Baker: While sitting here listening to Mr. McKinley's good talk on Central Station power, I wondered what I could hope to add. There are a few points, however, that I would like to emphasize, and in passing, would particularly like to call the attention of those of you who are interested in the use of power to a few of the very basic principles on which a large central station really stands.

The whole economic problem, of the Central Station today is, that it should be a "regulated monopoly." Mr. Insull, who has been interested in Central Station units since 1881, I believe, has talked "regulated monopoly" since a few years after that time, and I think that most of the large Central Station operators have agreed with Mr. Insull that to be successful in the production of power in large quantities, it must be a monopoly. Monopoly, if regulated, means larger volumes of business and better rates to all. In Chicago, particularly, were the lighting load, the power loads, and the transportation loads—surface lines and elevated railways—all produced by different generating stations, it would mean tremendous peaks on each station, very low load factor on all, and, consequently very high cost to the user of light and power, and a relatively high cost to the transportation people. In Chicago, Mr. Insull was able to attain success in this monopoly. It has been well regulated, and at present is under control of the State Utilities Commission, and all our schedules are passed on by them before we pass them to the user. By monopoly, on what loads we have at present, we are able to produce such a large volume

of electricity that the rates are phenomenally low. The surface and elevated railway rates there are lower than the cost of production, even in large quantities, for private plants. The transportation load in Chicago is about 600,000,000 kw. hours a year. Purchasing it from our large central station has enabled the Power Company (The Commonwealth Edison Company) to quote very low rates to the small consumers of power and has been an all-around feature in the reduction of rates.

Another advantage that I should like to emphasize is the specialization feature of Central Stations. I do not think any steel plant, unless it be the U. S. Steel Corporation, spends very much time or money in placing the responsibility of power generation in hands where they make a constant study of something twenty-five years in advance. That is really what the Central Station is doing. Very few steel companies send men abroad for little knowledge they may gain on power problems, yet this is something that takes place frequently and pays well in our business. Also, I think the Central Station has been a great feature in getting economies that are now possible in steam power development. We have just heard about the tremendous reduction in economy of large turbines, and I think the machine people agree that they were largely driven into the large units and better economy by the large central stations, such as our company and your company here. It has been a wonderful progress, the Central Station having the advantage of course of being able to use these tremendous large units that have been described.

Another question that is vital with Central Stations is the question of rates and contracts. Mr. McKinley covered that pretty much as we see it. There is one thing I would like to emphasize: that is the policy of our company and most of the large Central Station Corporations is to produce power and sell it as cheaply as possible, giving the man that puts his money into the investment a reasonable return for his money. We make reductions in rates without being compelled to do so. This has come to be the policy of every large central station. These reduced schedules, after they are worked out by our organization, have to be approved by the Public Utilities Commission, and when once on file, that

is absolutely all we can quote to a customer, and when we present our contract with its effective date on it, you may know it is the last word; there is no coming back and getting something better. That is one feature of regulation which we all like; it is good for the seller and good for the buyer.

It is our policy to give a liberal demand period, our demand being the average of the three highest half-hour kw-hrs. consumption periods of any month. Graphic records are made of kw-hrs. consumption for every half-hour period of the month and the three highest taken from monthly record of average. With our system of metering we can furnish the customer his load for any half-hour period during the year.

E. T. Selig: Mr. McKinley and Mr. Baker have covered the subject so thoroughly, that all I can do is to emphasize one or two points. One particular advantage that you will find with Central Station power is the facility of increase in capacity. I have in mind one steel plant in central Pennsylvania, which last year wanted about 400 kw. of power, with a possibility of their load amounting to 800 kw. They had very seriously considered installing an exhaust-steam turbine, but finally concluded to take Central Station power, expecting that their cost would run about 11 mills per kw. on a consumption of possibly 250,000 kw-hrs. per month. Their business has grown more rapidly than they expected, so that their load is now 1500 kw., they are using about 750,000-kw-hrs per month, and their rate on the schedule, on which they expected to pay 11 mills, is now a little less than 8 mills. If they had installed exhaust steam turbines of 1000 kw. capacity, they would already have found it too small, and as they still expect to increase to 2000 kw., the chances are it would have been impossible to take care of their business had they not gone to a Central Station. There is hardly an industry but at some time or other finds a demand for immediate increase in power, and in almost every case they are told to obtain it from the Central Station, as it might not be possible to get immediate relief from any other means.

Another point I think would bear a little more emphasis, that of rates and stability of rate. In every state in which you find a steel mill, the Central Station works under a Util-

ity Commission. After a rate is once established, no change can be made at all without the permission of the commission, and if this change in rate involves any increase, the Commission will not allow any action at all without publishing a notice and an opportunity being given for every one interested to be heard, and they certainly would require the Central Station to show them sufficient reason for the increase. The Public Service Commission of the State of New York has been in existence six or eight years. In all that time there has been only one increase in rates allowed and that affected only some small consumers and did not affect steel mills that happened to be on that Station's service.

Mr. McKinley has spoken somewhat on the matter of power factor. In earlier days, Central Stations paid little attention to that, but when they came to putting in larger installations, they found the power factor was of considerable importance in the cost of generating and distributing. Most utilities are using two-base rates.

At Niagara Falls, all contracts call for 90 per cent power factor to be maintained, or in case the power factor is lower, the demand is increased proportionately. Some Central Stations use an 80 per cent. power factor, and others as low as 70. In a steel mill proposition, with which I have had some experience, I have found by the judicious use of synchronous motor-generator sets, and in one or two cases, rotary synchronous condensers, and carefully estimating the motor sizes, they have been able to increase the power factor and avoid all penalty.

Brent Wiley: The majority of central station companies offer 60-cycle power and the standard frequency as adopted by most of the large steel companies is 25 cycles. The lower frequency is selected by the majority of the steel companies as standard, due to the fact that more suitable designs of low speed motors for main roll drive may be secured as compared with the machines designed for the higher frequency. Statistics show, however, that the percentage of slow speed motors selected for main roll drive has been reduced materially during the last few years.

	Motors 100 r.p.m. and below		Motors 200 r.p.m. and below	
	No.	Per cent Total	No.	Per cent Total
to 7-1-13	32	19½	67	40½
7-1-13 to 3-1-16	11	11	17	17
Total	43	16	84	31½

It is to be noted that during the period since the middle of 1913 the number of low speed units, i. e. below 200 r.p.m., is less than half the percentage for the earlier period. While there will always be a few cases where low speed direct-connected units are desirable, there are comparatively few cases where motors of speeds higher than 200 r.p.m. cannot be used when connected to mill in a suitable manner by gear drive, thus for such cases 60-cycle motors would be equal in performance to 25-cycle apparatus.

Another point that is emphasized by statistics is the rapid growth of the use of central station power. Since the first of 1915 the Westinghouse Company has secured contracts for fifty units, approximately 120,000 h.p. Twenty-eight of these units will be served with central station power. This is quite a large percentage and is quite a contrast with the percentage of Central Station power to electric power total in the steel industry, the latter being approximately 15% previous to 1915.

Referring to remarks just made by Mr. Hodgkinson, he stated that the future development of economies in power stations would undoubtedly depend on higher steam pressure and higher degrees of superheat. While it might be practical to work along the same line regarding engine drive for rolling mills, undoubtedly the limit will be reached for these applications long before those which are practical for turbine drive, as applied to large central stations. For instance; the steam in a steel mill is distributed over wide areas to the various engines, which are necessarily located directly at the mill, thus scattered throughout the plant. Mr. Hodgkinson mentioned a possible steam pressure of 600 pounds and also a high degree of superheat. When one considers these conditions requiring the generation and distribution

f steam, as would be necessary in operation of steel mills by steam engines, the proposition does not seem to be very practical. In fact, under present conditions it is a known fact that there is quite a percentage of the steam generated in the average plant that cannot be accounted for from the standpoint of useful work; with higher steam pressures and higher degree of superheat, undoubtedly these losses would be greatly increased. Consequently it seems practical to consider that the more you can concentrate the generation of power and transmit it by such economical means as offered by electric power, the greater opportunities there will be for increasing economies from a power standpoint.

H. C. Fairbank: The turbine business in the year 1915 for all manufacturers was greater than any year, with the possible exception of 1912. In 1912, we were selling many units of the 7500, 8000 and 9000 kw. size. This year, most of the Central Stations that purchased the 7500 and 9000 kw. sizes in the past are buying 25,000, 30,000, and even 45,000 kw. units. They are selling that power to somebody, and that merely shows that the isolated plants are dropping out and industrial plants are buying, to a large extent, central station power.

Of course, as has been mentioned, where fuel is a by-product, as blast furnace gas, the proposition is more severe for the Central Station. It has been quite universal to consider blast-furnace gas to mean the installation of gas engines. We have been doing quite a little investigation on that subject recently, and I believe that if the steam turbine operated under favorable conditions, that is central station conditions, in a steel plant, that it can deliver power cheaper than the gas-engine plant. I believe there will be quite a field for the steam turbines in steel plants even where they are already contemplating gas-engine installations.

C. S. Lankton: Mr. Fairbanks raised a question. Can the Central Station compete with blast furnace gas? I would like to have Mr. Menk say a word on that.

C. A. Menk: I did not expect to be called on, and haven't prepared anything. I enjoyed Mr. McKinley's paper very much. Without doubt, the Central Power Station will be the next thing on the program, especially where you need power in a hurry, such as has been outlined. We are on

both sides of the fence, both producer and seller, so it is pretty hard to give you my views, because it may conflict with the other side. So, therefore, I believe I had better not say anything further.

R. S. Orr: I came to the meeting tonight to listen—not to talk. The many interesting points brought out by Mr. McKinley and Mr. Baker and other gentlemen confirm the conclusion that I had previously reached, that if it is in accordance with correct economic principles for the central stations to furnish all or the greater part of the power used in the territory in which they operate, that that situation is bound to be realized and I think that the art of developing and distributing electricity has brought us to that point.

By way of emphasis, I wish to repeat one or two points that have been made. On account of the larger sizes of generating units that are now available, the unit cost of generating equipment has been reduced; it is very much less than the unit cost of small size units. That is the first point where saving can be made by the general use of Central Station power. The second is that these larger units are more efficient. That means there is a real—not merely an apparent—conservation of natural resources. There is a saving of fuel. The third is that the supply of power by Central Stations takes advantage of the diversity factor, reducing the amount of generating machinery needed and thus affecting a saving of money. In still another respect the supply of power from Central Stations effects an economy; the individual manufacturer must not only have sufficient machinery in his power plant to supply his maximum demand but he must also have spare units installed or suffer the inconvenience of shutting down portions of his manufacturing establishment while he is making necessary repairs to generating machinery. The concentration or combination of spare units into one central power plant manifestly means the investment in less spare generating machinery.

Now, there is another point. If a Central Station has concentrated at one point a tremendous capacity in machinery for generating power, it will pay that Central Station, as a matter of business, to employ the very best experts it can possibly secure to study operating costs and to work constantly towards reducing them.

These things that I have mentioned are all in favor of the ultimate adoption, or ultimate use, of Central Station power almost exclusively. There is only the one off-set to that—the cost of distribution. The improvement in the art of distributing, or transmitting electric energy at high voltages has reduced that difficulty to a minimum. The suggestion has been made that where blast-furnace gas is available, there is no possibility of the Central Station competing. I am rather inclined to think that is correct, but it seems to me that if the true principles of economy be followed, that power should be generated at the steel plant only to the extent to which it can be generated by the use of blast-furnace gas. There is no reason why the power plants of steel companies, and other manufacturing companies, that are too good to throw away and are being operated with a good degree of economy, should not be supplemented by being connected in with a Central Station system of distribution where additional power is needed.

W. H. Cogswell: The various gentlemen this evening have impressed you with the fact that the power companies have an adequate power supply, well arranged contracts and satisfactory prices. Let us then consider the application of this power. We have had considerable experience in the application of large motors to steel mill drives and the results have been highly satisfactory. I think therefore, it might be interesting to consider at this time the use of electric power directly to the making of steel. There is unquestionably a big demand for high grade carbon and alloy steels, to which the electric furnace is admirably suited. From the latest reports, I understand that one corporation making electric furnaces have sold approximately fifty five in the last year, in which the average charging capacity is six tons. These furnaces making approximately four heats per day, represent a large tonnage in high grade steel ordinarily known as crucible quality. The results obtained from the operation of these furnaces have demonstrated that they possess certain advantages over the crucible furnace and the only limiting feature to the advancement of electric steel making is that of electric power. It would seem to me out of the question to expect any large development in electric steel making if the furnace operator is ob-

liged to generate his own power. Electric furnace development therefore is absolutely tied up with central station development.

W. T. Snyder: The Central Station people seem to have made a pretty clear case, viewing the thing from the Central Station's standpoint. They have lots of power and at reasonable rates. It would seem that all the steel plant people should do would be to go to the Central Station people, get a contract, and sign up. But there is another side to the story. It would be very nice indeed if our plants were supplied with central station power and no power plants to bother with. On the other hand, we have our waste heat, our blast-furnace gas. We have steam engines installed, and we have available low pressure exhaust steam. Our managers would be glad, indeed, to be relieved of the bother of running power plants, and maintaining their organization, but they have this other question to consider, and unless the Central Station people have some suggestion to offer to take care of available waste fuel, it seems as though there is a limit to the amount of Central Station power that the steel mills will use. It is not to be expected that plants will consider buying Central Station power and allow this by-product to go to waste.

E. Friedlaender: We have been hearing mostly from the Central Station people this evening, and I would like to say something from the viewpoint of the consumer.

When we talk about generating power cheaply, we practically mean raising steam cheaply, as the steam cost is approximately 80 per cent. of the total generation cost. Therefore with the waste-fuel and cheap coal available at our mills, we should at least be able to keep our steam costs as low as the Central Station people. Then, in order to get a maximum economy, we would be compelled to take out our small generating units and replace them with units as large as the Central Stations are installing, and we are now at a point to consider doing this unless Central Station power is brought to our works, as required, at an equitable rate. For quantities over 2500 kilowatts, this rate should not exceed one-half cent ($1\frac{1}{2}c$) per kilowatt-hour. I have no doubt but that steel-mill managers, when figuring on building new mills, would rather figure on buying their power than to include in

their figures the large sums necessary for a power-house installation, and to set aside the room required therefor.

Heretofore it has been the custom of steel-mills to install only sufficient generating equipment to take care of their present needs, and make additions in small units, as required. This has been a great handicap so far, for, if in making the initial installation large units were employed, with a view to taking care of additional needs in the future, the best argument of the Central Stations would be overcome.

There should be no trouble experienced in selling power to mills in these times if more intelligible contracts were offered us, so that we could figure out, in advance, what any future consumption would cost. Our managers are not interested in load factors, diversity factors, maximum demands, peaks, etc., all they are concerned about is the amount and cost of energy required.

I do not think that the maximum demand meter has any right to be installed in our mills. Our managers probably would object to paying larger bills for months having lower power consumption than the previous months.

A large mill would give a fairly steady load on the Central Station and should be very desirable, as the load is practically continuous, day and night, throughout the year.

As power factors in modern steel mills average over 75, and in some mills are close to unity, there should be no restrictions as to power factors.

I think we should pay only energy charges, and not demand charges. In cases of business depressions and mills shut down, demand charges would be an excessive hardship on the mills and the Central Station should be willing to stand part of this hardship. Central Stations are not affected greatly as mills during business depressions.

F. B. Crosby: I do not feel that there is a great deal I can add. I would like to see more of the side of the question discussed from the consumer's standpoint. I think there are a good many here that feel the same way. The electric manufacturer, I think, must maintain a rather neutral attitude on this question. We do not care who buys, so long as they both buy. If I am allowed to express the opinion, I think the extension of Central Station power has

been remarkable in every direction. I have been surprised that no person made this prophecy—for which I claim no personal credit—viz.; that within the next few years, possibly 15 or 20, within the recollection, I hope, of all of us here, there will be a monopoly of Central Station power that is at present undreamed of, except by some of the truly great men of the country. I think we will see the source of eastern power in the coal fields. It is a wonder that some of that has not been accomplished. Many of the coal interests are controlled by the railroads, but with the coming electrification of the railroads, there will be centralized power. Whether we may wish for one or the other, we are bound to be obliged to face the future, and I can see, for my part, no possible solution except that sooner or later everyone that uses power will be buying from a monopoly, and let us all hope and pray it will be a regulated monopoly, for it is bound to come.

Unfortunately, I am often placed where I have to either answer or evade the question: "which is preferable, for you to purchase power from a Central Station or supply your own." It is a question I don't like to have to answer. I would like to be in a position to come out and say what I believe; but I am not in a position to know both sides of this question.

Some of the larger stations are in a position to provide both 25 and 60-cycles. With the steel mill man in years past it has been almost entirely a question of speeds. During the last four or five years, there is a steadily increasing tendency towards high speed motors; that is coming about through change in steel mill practice. The practice in rolling steel has often been the reason of reducing the speed of the motor. How far that will go it is beyond me to say. Some of these installations have been in operation successfully four to six years.

E. J. Dittmar: I am pleased to have been here tonight. I heartily agree with a statement that was made, that the motor has its advantages over the old steam engine drive in several ways, particularly in its simplicity of control, and also in the constant speed maintained. It gives a more uniform finish and cross section of material rolled. As a small industrial plant, we are purchasing power from a Central

Station, for possibly one great reason, and that is we don't have the space to install our own power plant, or perhaps the space is set aside for other purposes. I might say, as a matter of interest to the Association, and also as a testimonial for Central Station power, that we will probably consume this month about 1,000,000 kw-hrs.

S. C. Coey: There are two points that interest me especially, namely: the difference in the standard frequency used and the method used in determining load factor.

Two of the speakers have already referred to the difference in frequency usually encountered in considering the use of purchased power for our own plant. Most of the steel plants are standardized on 25-cycle, and most of the Central Stations are standardized on 60-cycle. If we are considering the use of Central Station power in existing steel plants that use 25-cycle and the Central Station is supplying 60-cycle, there is the added factor to take into consideration of changing this power from the 60-cycle current to 25; and frequency changer sets have about the same efficiency as motor generator sets, or about 85 per cent. efficiency. This added loss makes it hard to show a saving even with the big unit the Central Station is putting in.

In Mr. McKinley's paper, he defined the load factor as the average power over the maximum recorded for a certain assumed length of time. It seems to me that when he came to the per cent. of the steel plant, he began to get away from that definition. He took an installation that had a load of 3000 kw. and three 1500-kw. turbines installed and gave an average load factor for the year of 50 per cent. He probably is figuring on an average load for the year, as I understand it, of around 2250 kw. and used his total kw. capacity installed in arriving at his load factor. I assume that condition, because I happen to know a large number of steel plants are running 50 per cent. load factor and figuring it in that manner. In going over reports of Central Stations, I notice the load factor in Central Stations in the United States runs between 25 and 30 per cent. if figured in that manner. I just call this to their attention to show what a choice load a steel plant is compared with electric railway, or even ice plant load. We have a load here that is a practically constant load from Monday morning, to at

least Saturday night, and gives a relatively large percentage of the load even over Sunday in plants that have blast furnaces and steel installations.

E. Chesrown: I have been interested in these talks by the Central Station men, and particularly, in the remarks of Mr. Friedlaender. We notice a difference in the position taken by the gentlemen who are speaking from a Central Station point of view, and the mill people through their operating department. I would like to have an expression from the Sales Department of the Steel Companies as to what they would do in the way of making rates on steel for instant delivery. It is a fact that in Central Station practice there can be no provision made in advance. When the demand comes, the operator closes his switch and the Central Station man supplies any demand which that particular customer places upon him. In steel production, there is a schedule laid out ahead. An order for steel enables the steel man to place that order on his schedule to produce the steel at some time when it is economical in his schedule to do so; so that the question of economical loads and prices of steel and power is not at all parallel and cannot be made parallel in any way. One is an instantaneous demand, just as if a steel mill was called up by telephone to deliver 1000 tons of products within a few minutes, of any particular size and quality. I do not think you can make rates or prices on steel under those conditions.

Another feature that enters in here is the question of blast-furnace gas. It is probably true that, in those plants where there is a considerable blast furnace production, it would be impossible for the Central Station to compete up to the capacity of the utilization of that gas, but any plant that I have seen where there is blast furnace gas you will also find a considerable demand for reheating furnaces. I have talked to considerable extent with operating men along that line. There does not seem to be any legitimate reason why blast-furnace gas cannot be used for reheating where it is just as efficient as for power generation, while operating under conditions where they are more suitable, due to the fact of their being used where power cannot be directly applied, and leaving the field for Central Station, or other source in power to rolling or other operations of the mill.

If the gas is so applied, we will generally find that there will be a considerable production of power as a result of direct coal firing in plants of any size. If Central Station power is applied to those plants, it will be easy to shut down one or more boiler plants, and in that way effect reduction of cost in operation.

If we go into a steel plant where mills are already supplied with engines in good operating condition and simply supply an auxiliary portion of their power, it is not practicable to make rates such that Steel companies can afford to use the power; but if in making this application it is possible to shut down one or more boiler plants and apply Central Station power to existing mills where the machinery is pretty well deteriorated, it ought to be possible to make a sufficiently large initial installation so that the whole plant can earn a rate low enough to warrant an installation. There isn't much question about the application of Central Station power; the question is getting a start in an existing operating unit.

F. W. Funk: There certainly were a great many interesting points brought up this evening. The thought occurs to me, that in getting down to this rate matter and to power cost, that the most usual difficulty encountered by Central Station men is to get the steel man, or consumer, whoever he may be, to take into account all his cost. There are a great many superficial and well-recognized items that are taken in, but to get him to include all his cost, in order to get a comparative figure, that seems to be the difficulty.

J. S. Jenks: In reference to the application of Central Station power to steel mills, I will cite you one or two circumstances with which I am quite familiar. Today, Central Station drive holds the world's record for production on a 6-mill stand, which averaged over 100 tons per hour per month. The same steel mill has been using Central Station service with relatively high speed motor with a gear for over a year which, to date, has not worn to the extent of eliminating the original tool marks. The load factor on that mill has been improved by co-operation of the Central Station, the management and the mill men to an extent that no other steel mill has ever reached. There was some difficulty in the beginning because the rollers thought they were be-

ing curtailed in capacity and hindered in earnings, but after some study of the matter, there was an electric horn installed, so arranged when peaks exceeded a certain limit it gave a signal. Since this device of signalling the mills, keeping down the peaks and increasing load factor has been installed this mill has made the phenomenal record of which I told you.

Speaking about value of load factor, I can cite you cases of steel mills running from 40 to 55 per cent. load factor, which are supplied from Central Stations having a load factor of over 70%. Hence, you see, there is not a great advantage to the Central Station in the average load factor of a steel mill as the Central Station has to secure consumers having a better load factor or a diversity which will improve the load factor of the steel mill.

There have been some remarks made about the relative advantages of 25 and 60-cycle motors for mill service. I just wish to state that I am familiar with quite a number of 60-cycle mill drives which have proven very satisfactory over quite some years of service, and a short time ago a high power reversing drive was put on the market by a reputable manufacturer who is willing to undertake blooming mill drives of units of over 1000 h.p.

C. S. Lankton: There have not been very many questions asked of Mr. McKinley. There have been some things talked about that we would like him to speak a word about. There is one question I would like to ask: "Under what condition and in what quantities can $\frac{1}{2}$ c power be furnished? We would like to know what we would have to do to get it.

Jos. McKinley: I am not prepared to answer that. Mr. Orr can answer you.

R. S. Orr: With large loads and very high load factors, we can do it.

Jos. McKinley: Various questions have been answered by other speakers. Mr. Chesrown, I believe, gave the Central Station's point of view on Mr. Snyder's and Mr. Friedlaender's questions. As to the type of rate schedule or contract, that is a matter I think, with a little joint effort on the part of this Association and Central Station men, that possibly something could be made that would suit all conditions. A flat rate could be made, but with so many restrictions on

it that it would not be nearly as clear as the so-called two-base rate. A flat rate, such as used at Niagara, in times of business depression, would swamp the average consumer. A party entering into a contract of that kind has to assume a risk of the future. Further, in regard to the use of waste gases and heat, if the total gas supply can be utilized in the generation of power and there is no use for it in other departments of the industry, it is very questionable whether any Central Station could supply power to compete with that. If there is an abundance of that gas, more than the requirements of the industry, it would be a proper question for the Central Station to take up the use of the remaining quantity and go the steel mill one better. The only advantage the Central Station claims is on account of its being a monopoly; it has a diversity factor and load factor that no single unit can enjoy.

LATEST DEVELOPMENTS IN NEW APPARATUS AND APPLIANCES

By ELECTRICAL DEVELOPMENT COMMITTEE, A.I. & S.E.E.

W. T. Snyder: The meeting this evening will be under the auspices of the Electrical Development Committee, and will be directed by the Chairman of the committee. This committee is composed of men particularly qualified in different phases of generation, distribution and application of electricity in the iron and steel industry. It is the function of this committee to be in touch with the latest practice and progress of the various branches mentioned and keep the membership informed, and to act as a clearing house between the members that are doing things and the members that want to know what is being done. It is not the object of this committee to recommend or condemn any particular line or make of apparatus, but rather to confine its dealings and deliberations to fundamentals.

S. C. Coey: The method of conducting this meeting, as regards papers, will deviate slightly from our regular custom, as we are figuring on each individual line of the subject to be covered by an expert of that line. It is the intention to make each of these talks as short as possible and to complete the reading of the subjects before we open the meeting to discussion. The first talk of the evening will be on Prime Movers by Mr. Breslove.

Jos. Breslove: Within the past few months orders have been placed by various steel companies for about twenty large blast furnace gas engine units, an additional number were installed during the year 1915, and several are now being contracted for. It would, therefore, appear that there is a revival of interest in this form of prime mover in con-

nection with the iron and steel industry, and it may be profitable at this time to inquire briefly into the conditions which have brought this about.

It is not the intention to re-open the discussion covering the technical merits of the steam turbine, turbo-blower and gas engine plants. This has been covered from all sides by several excellent papers, and it is only as a matter of interest to the members that the gas engine is being touched upon.

Electric drive in steel mills has made rapid strides and there is now required an enormous amount of electrical energy for this service. This has enhanced the value of the gas resulting from blast furnace operation. In 1908-09 when the large gas engine plants were installed at South Chicago and Gary, the heat value of the furnace gas was about 100 b.t.u. and even greater values were not unusual, whereas present operation results in a gas containing about 90 b.t.u. In other words, the demand for electrical energy has been greatly increased, while available b.t.u. from the furnace has decreased.

In the operation of the blast furnace, a definite quantity of the furnace gas must be burned under the hot blast stoves for heating the blast and the remainder is available for use in the cylinders of gas engines, either for supplying the blast or generating electric power, or it may be burned under steam boilers supplying steam blowing engines or turbines. It can be shown that in the operation of two 500-ton furnaces, assuming one ton coke per ton iron, the net power available after deduction of the gas required for heating the stoves will be:

- (a) Gas Blowing Engines and Gas Electric Engines—15000 kw-hrs.
- (b) Gas Blowing Engines and Steam Turbine Electric Units—7500 kw-hrs.
- (c) Steam Engine Blowers and Steam Turbine Electric Units—4500 kw-hrs.

or, in the production of 1000 tons iron, there will be a net saving of approximately 10,000 kw-hrs. in the use of all gas engine units instead of all steam units.

The introduction of the electric furnace, the increasing number of motor drives for steel mills and the growing tend-

ency to ally the blast furnace with the plant producing commercial shapes, makes it desirable to utilize the blast furnace gas in the most economical manner, which is undoubtedly in the cylinders of gas engines. This factor is the chief argument for the gas engines now being installed or contemplated.

The large engines now on contract by the Company with which the writer is connected, are both electric units and blast furnace blowers, totaling eighteen units. Of these, eleven units are for the Indiana Steel Company, Gary, Indiana, and consists of four-44x60 twin tandem engines direct connected to 3000-kw., 83 $\frac{1}{3}$ r.p.m., 25-cycle alternators, and seven 42-74x54 twin tandem gas engine driven blowers. Three units for Illinois Steel Co., S. Chigaco, Ill., are 44-78x60 twin tandem gas engine driven blowers; three 44x60 twin tandem engine direct connected to 3000-kw. alternators for the National Tube Co., Lorain, Ohio, and a similar unit for the American Steel & Wire Co., Cleveland, Ohio.

The Electric units are similar in design to those which have been in operation at various plants for the past eight years. The blowers, however, involve a new design of air end, a brief description of which may be interesting. The air cylinders have automatic plate valves throughout for both inlet and discharge, these being of the same general type as are used in certain air compressors. The valves in these engines are located in belts around the cylinder at each end and arranged so that a set consisting of one inlet and one discharge valve can be removed for inspection without disturbing any other part of the cylinder. This design obviates the use of any valve gear in the air end which permits higher speeds than possible with cylinders which involve the use of a mechanically operated gear. The higher speed also permits a smaller engine for a given service resulting in material saving in the first cost of the installation. Piston speeds of about 800 feet per minute are possible with these engines, as against 500-600 feet per minute with the mechanically operated gear. The cylinder heads contain an unloading device consisting of additional clearance space which may be added so that a higher blast pres-

sure can be obtained with a corresponding decrease in the quantity of air delivered.

Cheap fuel has led to an enormous wastage in the production of coke, which has heretofore been made almost exclusively in the familiar bee-hive. In Europe, the waste heat has been carefully conserved and burnt under waste heat boilers while by-product coke ovens have been used extensively. These are now being introduced in this country and the bee-hive oven is bound to disappear. Coke oven gas contains 500-600 b.t.u. per cubic foot about the same as illuminating gas. It is satisfactory fuel for gas engines and is largely used in Europe. There are only a couple of installations in the United States, but these will undoubtedly be increased, and the use of gas engines in connection with coke oven gas presents a large field for the economical and profitable generation of power.

The old question of first cost, maintenance and reliability is bound to present itself. This may be answered satisfactorily by the fact that most of the units mentioned are repeat orders from those who have used this type of engine for seven or eight years. The gas washer of today is a comparatively simple piece of machinery and both the initial cost and maintenance of the gas engine installation have been materially reduced in consequence.

The cost of a complete blast furnace gas engine plant, including washers and tanks, is somewhat in excess of a modern condensing steam turbine plant with boilers and auxiliaries, but its reliability is equally as good and its fuel economy superior.

The steam station which has made the best record for economy is, I believe, that of the Interborough Rapid Transit Co., N. Y., where there are installed some 30,000 kw. Steam Turbine Units. These are two cylinder high speed machines operated at high steam pressures, superheat and high vacuum and under these conditions the thermal efficiency of the turbine unit alone is over 24%, a truly remarkable result. The average steam plant with much smaller units operating at the usual steam pressures and vacuum cannot nearly approach these results. In addition, it is to be noted that the power absorbed by the condensers must be deducted from the performance of the steam turbine, and

that the efficiency of the boilers under which the blast furnace gas may be burned is less than unity. On the other hand, there is no reason why a gas engine of average proportions should not have a thermal efficiency of 20 to 25% from which it is only necessary to deduct the power consumed in gas washers and cooling water pumps to obtain the net efficiency of the gas engine plant.

The author has had considerable experience with the modern steam turbine plant and is not unmindful of its many good points, neither does he present the gas engine as a panacea for all steel mill ills. However, where blast furnace gas is available and condensing water scarce, the gas engine may be installed to advantage and it should be given careful thought before deciding on the type of prime mover that will best fit the situation.

The steam turbine plant has the advantage of low first cost and practically unlimited capacity per unit, wide margin for overloads and good steam economy over a wide range of load. On the other hand, with insufficient blast furnace gas, boiler operation will call for coal storage and ash removal and the operating economy is largely dependent on the station attendants. The turbine condensers also call for a large quantity of cooling water. In order to obtain the high economies with which we have become accustomed to associate the steam turbine, it is necessary to use high steam pressure, a fair degree of superheat and above all things high vacuum. The latter involves cooling towers or spray ponds where water is scarce. It will be admitted that the combined plant calls for a considerable degree of intelligence in its operation and that a plant of this character involves many individual considerations to obtain the continued high economy of which it is capable. Pitted against the turbine advantages is that of the gas engine which requires no boiler plant and is always ready for immediate operation and requires but a small quantity of cooling water. The size of the units is limited, however, and the economy falls off at light loads. With the prevailing conditions in iron and steel work and the increasing demand for electrical energy, it would not be surprising to see a greater demand for blast furnace and coke oven gas engines in the near future.

S. C. Coey: It is rather interesting to note that the special development in the blowing unit, viz.; the plate valves, which have only been brought to the front in this country within the last two or three years have been in use in Europe for about ten years. There are a number of developments that have been in use in the European countries and are just getting to this country; one of these being the Iron Clad Switch Board which will be touched on tonight by Mr. Pauly. This should be a very interesting feature to the Association of Iron & Steel Electrical Engineers, as it contemplates using up some of our product.

K. A. Pauly: Every one who has given the matter even the slightest consideration must realize that to the predominating characteristic of the safety first idea—its so evident reasonableness—must be attributed the great force with which the movement has spread all over the country.

Numerous companies are spending considerable sums to educate their men along the lines of safety; committees are everywhere being formed to inaugurate plans for improving industrial conditions; and innumerable safeguards are being introduced wherever applicable.

It is oftentimes difficult or dangerous to make repairs or changes back of a live switchboard, especially in cases where the space in which to work is limited. These features are entirely eliminated with the safety first unit.

Panels can be obtained for the control of generator, motor and feeder circuits, and are particularly adapted to plants where electrical distribution to various buildings is made from economically located distribution centers. The construction is such that extensions can be readily made or the units moved to other locations to meet changed or new conditions.

All live parts are enclosed, and the opportunity for an operator to come in contact with the circuit is practically eliminated.

When it is desired to make tests on instruments or meters of any unit, that unit can be removed and another substituted until the tests are made, which obviates the need of shutting down a section of the switchboard.

A spare removable unit can be used to reduce the time of shut down for inspection or repair. Busbars need not be

killed, disconnecting switches need not be opened, leads and small wiring are not disturbed. The design of the units is in accord with the best engineering practices. The oil switches, buses and all live parts are in compartments, which tends to reduce fire hazards and limits disturbances to a single point.

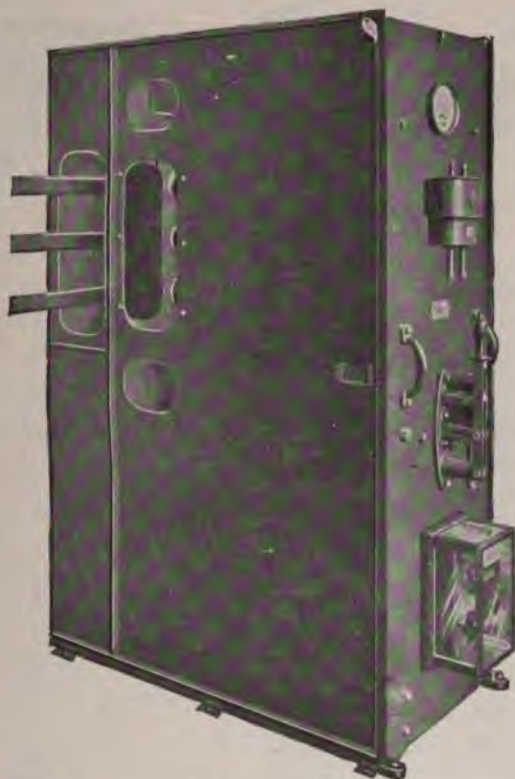


Fig. 1—Removable Truck Switchboard (closed).

The stationary member of the removable truck switchboard carries current and potential buses with their disconnecting switch studs and barriers between the current studs to prevent accidental contact by anyone that enters the compartment. The rear end of the current disconnecting switch studs run to buses and incoming or outgoing leads; the potential buswires to small contact studs near the top of the compartment.

The removable truck is mounted on wheels. The forepart carries a sheet steel panel on which is mounted the instruments, meters, oil switches or other appliances usually mounted on the ordinary slate switchboard panel. The current transformers are mounted on steel brackets back of the



Fig. 2—Removable Truck Switchboard (open).

instrumental panel. The rear of the truck carries the movable parts of the disconnecting switches, the potential transformers and small wire accessories. To center the truck and to assist in placing it in or removing it from a compartment, rails fastened to the sides of the compartments are furnished. The oil switches, instruments, meters, trans-

formers and all adjunct parts can be removed entirely from the installation by wheeling out the truck.

The side-walls are provided with hand-holes, so that the busbars and buswires can be continued from unit to unit. On the exposed walls of the end units these openings can be closed by removable covers. Access to the rear of a compartment can be had by a two-section sheet steel door.

To remove or replace a switch unit, the oil switch must be opened and therefore the load disconnected. This is provided for by an interlock attached to the oil switch operating toggle, which engages cast lugs on the walls of the stationary unit. With the oil switch closed it is impossible to remove or insert the truck. The value of this feature needs no discussion.

The field of application of these units as regards voltage and current is of course not unlimited. The voltage limit is established at 7500 volts in this design, which agrees with that of the ordinary switchboard not using remote control apparatus. However, by special design these units may be used up to 15,000 volts and 300 amperes. The current on the main bus in the stationary element is limited to 2000 amperes at 60 cycles and 3000 amperes at 25 cycles. The current capacity of the removable element is limited to the size of the oil switches which it seems advisable to use in a structure of the kind described—500 amperes at 2300 volts and above, and 800 amperes up to 600 volts. The present units have a single set of buses only. A double set would change the simplicity of the arrangement.

Removable safety first switchboard units can be used on single, quarter, or three-phase circuits.

S. C. Coey: I know there are a number of questions we would like to ask about these various points that are brought up, and I wish you would all make notes of any special questions you would like to bring up. We will carry the program through and then, at the end, we can bring up these questions.

The next subject for consideration tonight is Transformers, upon which subject Mr. Steele will give some data.

H. G. Steele: Late developments in transformers are not startling. Transformers are so simple in mechanical design and have been so well developed that few radical de-

developments are made from time to time. The improvements in transformers are more in detail. Probably everyone will agree that a transformer is the most reliable piece of electrical apparatus manufactured, having no moving parts and being entirely enclosed in a case, with very little to get out of order if reasonable attention is given to it once in a while.

Improvement in Self Cooled Case—Oil filled, self cooled transformers have been made with very great capacities but up until recently, it was not feasible to build sizes larger than 1000-kv-a. without some external appendages to help cool the transformer, such as radiators and tubes.

These appendages, such as radiators and tubes, complicate the case design by reason of the fact that the case itself must be drilled with many holes for the openings to permit the oil to circulate from the case through the external radiators and tubes. Now, every time a hole is put in a transformer case, one more chance for oil leakage is permitted. Therefore, it is highly desirable to have just as few openings into the transformer case as possible below the oil level.

A further complication and danger with the radiator or tube type tank is possible if the oil level drops below the radiator and tube openings in the top of the case. All radiation is stopped so far as the radiators and tubes are concerned, and since the radiators and tubes are depended upon and furnish practically all of the cooling, it is plain that the transformer will be in danger.

Within the last year there has been developed a transformer case, having no external radiators or tubes, for large self cooled transformers, of practically the same construction as tanks used on ordinary sized transformers such as 100 kv-a, 500 kv-a and 750 kv-a. This new case is cooled without the addition of external appendages such as tubes and radiators, and has been furnished in sizes as high as 4000 kv-a. Some of this type have been installed at the Bethlehem Steel Company.

This transformer tank is a plain, vertical, corrugated case, without tubes and radiators, and without any external appliances for cooling. Therefore, the important development accomplished is the ability to cool units larger than

1000 kv-a. without the use of radiators, tubes, water cooling or forced oil, and at no increase in cost.

This development means less complication, less likelihood for leaks in the transformer case, because there are no extra holes in the tank, and less danger from decreased oil level.

High Reactance—There has been a steady advance towards higher reactance for transformers. There is on the market today a mill type transformer, specially designed for steel mill service, one of the features in the design of which is a higher inherent reactance.

Higher reactance in a transformer means durability, safety and continuity of service, which seem to be the first three important specifications for any piece of electrical apparatus used in a steel mill. In fact, inherent reactance in electrical apparatus is one of the principal sources for protecting the apparatus itself. Large generators are being installed with power limiting reactances for protection, and the speaker would recommend that high reactance take its place in the specifications for your transformers in equal importance to regulation, core loss, copper loss, etc., and it will not add appreciably to the expense of a good sized transformer, say 500 kv-a to 2500 kv-a. units, to specify that the reactance be not less than 3% and up to $7\frac{1}{2}\%$.

To obtain high reactance inherent in the transformers, it has been common practice generally to design for this reactance in the windings and core. There has been developed a means for getting higher reactance without compromising the design of the windings and core. This is in the form of a reactance coil, mounted in the top of the transformer case but external to the windings.

This method adds very little to the cost but adds considerably to the durability of the transformer—for not only does this separately mounted reactance add to the inherent reactance of the transformer, but it tends to retard or dam back surging or the effects of lightning before such shocks reach the windings themselves.

The reason this separately mounted reactance inside the transformer does not add much to the cost of the transformer is because the case holding the transformer will also hold the reactance coil, and the same bushings that carry the

current to the transformer will also carry current to the reactance coil, which is, therefore, much cheaper than a reactance mounted separately from the transformer case, which would require its own case (if oil filled), its own bushings, and space outside of the transformer to mount it.

This separately mounted reactance inside of the case is not a power limiting reactance, because it is comparatively small in capacity—but it is a reactance that acts as a buffer between the line and the transformer, tending to choke or dam back sudden rises in voltage from surging or from lightning.

This separately mounted reactance inside of the transformer case may be likened, in rough analogy, to a safety valve on a boiler, because if the shock which this reactance is obliged to carry happens to be too severe for its capacity, the coil will blow up but the current will find its way to ground before it reaches the transformer windings themselves.

In the past it has been a most common specification to “extra insulate the end turns of the windings.” Now, the trouble with this is, if the shock delivered to the windings is so severe that the end turns will not stand it, then the end turns will break down, and if the end turns do break down, the whole transformer is entirely out of service and a complete rewinding is necessary, as a rule.

The difference between the safety and durability of extra insulating the end turns as compared with placing a separately mounted reactance in series with the transformer windings is, as stated, that if the shock is too great, the reactance coil may be shattered, but the transformer windings themselves are protected and it is a simple matter to go on operating by cutting out the reactance coil and connecting the incoming lead around the reactance coil to the windings temporarily until a new reactance coil can be secured. These coils are cheap and may be likened somewhat in practice to the use of fuses.

It seems rather strange, when we look back over the development of transformers, that this has not been done long ago. It is a simple, commonsense matter, requiring no laboratory to research it out, and the very fact that operating companies are spending large sums of money to buy re-

actances to protect generators, should make it plain that transformers should be likewise protected, especially when this protection can be gotten without much additional expense, as shown in the development which the speaker has described.

Transformer Bushings—In steel mill work, voltages higher than 22,000 volts are seldom used. There are a great many installations as high as 22,000 volts. In the higher voltages, which include 22,000 volts, the question of bushings is of great importance.

In a porcelain bushing the dependence for insulation is principally on the thin glaze of the bushings, and should that glaze crack or break, the bushing is dangerous. Transformer manufacturers and users have had plenty to think about to try to secure satisfactory transformer bushings. Great efforts have been made to secure something better than porcelain.

There has been developed and in use a type of bushing that is not porcelain. The sample which the speaker now presents to you is a bushing of molded insulation, the principal substance of which is mica. Attention is called to the fact that this bushing does not depend on a thin glaze (as porcelain) for its dielectric strength. This molded bushing is just as good dielectrically throughout its entire substance as on the surface, so if it is chipped or cracked, it will not fail, as a porcelain bushing often does.

This bushing is much superior to porcelain in mechanical strength. It will stand more abuse and rough handling.

It will take a thread the same as a piece of cast iron and, therefore, it can be threaded right through the cover and set up with a wrench in a thorough mechanical manner. It is not necessary to allow a clearance of $\frac{1}{4}$ " to $\frac{1}{2}$ " in the hole in the cover to permit the shank of the bushing to pass through, as in porcelain.

The space between the shank of a porcelain bushing and the hole in the cover makes it necessary to provide a flange, which must be cemented to the porcelain in order to close up the opening between the hole in the cover and the bushing to make the transformer weatherproof.

Therefore, the fact that this new type of bushing may be threaded and screwed right into the cover eliminates

the necessity of so many separate parts, as in a porcelain bushing.

Attention is called to the fact that the current carrying lead passing through this molded bushing is molded right into the material itself, so that there is no hole through the center of the bushing, whereas, in a porcelain bushing, it is necessary to allow a hole with sufficient clearance to clear the current carrying lead, and in order to make the bushing weatherproof, a metal cap must be provided on the top of the bushing with a weatherproof petticoat to keep out rain.

This new molded bushing, therefore, may be summarized as being a one piece bushing, embodying the insulating material, current carrying lead, and means for mounting it on the cover to make a weatherproof job.

A porcelain bushing mounted on a transformer requires several parts, namely, the porcelain insulation, the current carrying lead and metal cap, gasket, cement, and a flange with bolts. All of these parts add complication in manufacture and are not simple mechanically.

This new molded bushing does not show static at voltages as high as 100,000, which is, of course, a great improvement over porcelain for high voltage work. It eliminates the necessity of "oil filled" or "condenser type" bushings.

Terminal Boards—On the inside of the majority of large power transformers there is usually mounted terminal boards for voltage taps. These terminal boards are ordinarily made of wood.

A new type of terminal board which is now on the market eliminates the use of wood almost entirely. The material used for insulation is the same molded material as is used in the molded bushings described above.

In addition to eliminating wood as an insulator, the new terminal board mentioned occupies less space and is of skeleton structure, which allows a freer flow of oil in the top of the transformer where the oil is most efficient. The ordinary wood terminal boards take up so much space in the top of the transformer case that they act like a dam and tend to retard the flow of oil.

Transformer Oil—Transformer oil is not a new subject, but it occurred to the speaker that perhaps some points on transformer oil would be worthy of consideration at this meeting. In times like the present, when every plant is being rushed and steel mills particularly are trying to get all the capacity possible from every piece of apparatus, it is of vital importance to watch the condition of the oil in the transformers.

The copper and steel in a transformer will stand forcing better than the oil.

A systematic and regular test of transformer oil in service is, of course, advisable at all times, but when transformers are being operated under very heavy duty, it is the vital point to watch. The samples of oil which the speaker now presents to you show the process of disintegration from perfectly good oil to extremely bad oil.

Sample No. 1 shows new transformer oil in good condition. This is a pure, neutral mineral oil before any heat treatment. This oil has the following specifications:

Flash Test 265°F.

Burn Test 310°F.

Chill Test 28°F.

Viscosity 90.

Dielectric Test, 30,000 volts between
sphere gaps 2-10 of an inch apart.

This sample of oil while being satisfactory in dielectric strength and having good, free flowing quality, is low in flash and burning tests.

Sample No. 2 shows the same oil after being subjected to a heating of 212°F. for thirty days. The only effect on this oil is a slight darkening, making the oil a light canary color. Attention is called to the fact that there is no deposit of sludge in the bottom of the test tube.

Sample No. 3 is practically the same as Sample No. 1, except that it is a later distillate in the process, resulting in the following changes in characteristics:

Flash Test 360°F. compared with Sample No. 1 265°F.

Burning Test 420°F compared with Sample No 1 310°F.

Viscosity 84 compared with Sample No. 1 90.

This oil is a better transformer oil by reason of the fact that the flash and burn tests are higher, the viscosity is

lower, and the dielectric strength is just as good as Sample No. 1. You will note that Sample No. 3 is slightly darker than Sample No. 1.

Sample No. 4 shows the same oil as Sample No. 3 after being subjected to a heating of 212°F. for thirty days. The only effect on this oil is the slight darkening from a normal light yellow to a dark yellow. Attention is called to the fact that there is no deposit of sludge.

Sludge deposit is the most serious defect in oil.

Nearly all oil will deposit sludge if subjected to a high enough heat for a long enough time. Putting this in other words, in practical operation you may start transformers off with perfectly good transformer oil, but if the transformers are overloaded for a considerable length of time, it is just the same as applying abnormal heat to the oil, and almost any transformer oil will, under these conditions, show a deposit of sludge.

Oil that is not a good transformer oil will show much heavier sludge deposit, and since it is a difficult matter to get transformer oil perfect, the same as it is a difficult matter to get anything perfect, it is wise to watch transformer oil very carefully when the transformers are working hard, to ascertain whether or not sludge is being deposited.

Sludge deposit clogs up the oil ducts in the windings, coats the outside of the windings and the inside of the case, and thickens the oil. All of this tends to cause the transformer to heat abnormally. A transformer containing oil which is depositing sludge is slowly burning out, and if attention is not given to this matter, the transformer may operate for months and suddenly fail.

Samples No. 5, 6, 7, 8, 9, 10, and 11 show the progressive disintegration of the oil due to continued heating, which would be analogous to running this oil in transformers which were operating overloaded causing abnormal heating. Attention is called to the color of the oil in each test tube showing a steady darkening of the oil, with an increase in the deposit of sludge plainly seen in the bottom of each test tube.

Sample No. 12, shows transformer oil with about ten per cent (10%) water in it.

Sample No. 13 shows oil that has been subjected to abnormal heat, resulting in the deposit of sludge and, in addition, water in the oil, undoubtedly caused by the transformer sweating.

Sudden changes in temperature, particularly when transformers are not operating, cause the condensation of moisture, usually on the inside of the cover, and this moisture drops off into the oil. This is a fair sample of oil in such a case.

Sample No. 14 shows bad oil, to abnormal heat over a long period of time.

Sample No. 15 shows very bad transformer oil, which you will note is as thick as cylinder stock. This sample is the result of running very good transformer oil at an abnormal temperature for a long time.

As a matter of fact, this particular sample came out of a transformer operating in a steel mill where no attention had been given to the transformer oil from the date that the transformer was placed in operation until five years had passed, and during that time, the transformer had been at times heavily overloaded, which caused the sludge to deposit and it is not much wonder that the transformer failed.

Now, it ought not to be a hard task to get good transformer oil, but oil is oil, whether it is called transformer oil or automobile oil or cylinder oil, and it is a fact that transformer manufacturers are obliged to use the utmost care and take elaborate precautions to be sure that their supply of transformer oil has the right qualities for operation in transformers, and it is simply to sound a note of warning to the men who are operating transformers that, even though the manufacturers of the transformers furnish perfectly good oil when the transformers are shipped, this oil will deteriorate if some attention is not given to it regularly.

The most dangerous result, I repeat, is from sludge deposit, and yet this is the most simple thing to watch if you will only do it. Sludge deposit can be easily seen if a sample bottle of oil is taken from the bottom of the transformer and allowed to stand twenty-four hours.

S. C. Coey: I am sure we have all heard a lot of interesting data given on transformers. Probably a good many

of us will go home and look over our oil conditions to see if any of these facts are borne out in our own cases.

Going into special control, Mr. Gilpin will give us a little talk on Ore Handling and Car-Dumper Equipment.

C. D. Gilpin: The object of this paper is to review very briefly the general features of recent developments in coal and ore handling apparatus. The writer has not endeavored to cover the whole field, but merely such installations as have come under his own observation.

Taking first the subject of coaling docks, there is no doubt but what you are all familiar with the standard type of steam-operated lifting car dumper which first elevates the car vertically and then turns it about an adjustable pivot point. This style of dumper is practically a standard for loading boats along the lakes, but in the east there is also in extensive use a type of plant in which the contents of the railway cars are first transferred, by means of a turning dumper, into motor-operated larry cars. The latter are then conveyed, by means of elevators or inclined runways, to the top of a pier containing bins into which the larry cars dump their loads. The coal may then be transferred to the hold of the boat by means of spouts or chutes.

The object of these expensive piers is not only to provide a certain amount of storage, but also to allow coal to be fed to any hatch at will without moving the boat, which is highly desirable because in many ocean-going vessels a large part of the loading time is taken up in trimming the coal back from the hatches.

To obtain the flexibility of the bin system without its high initial cost, a new type of coaling dock has recently been installed in one of the Southern ports. The pier of this dock carries a runway next to the water edge and not very much above water level; on this runway travels a movable structure known as a loading tower. Behind this is another runway, elevated above the first by means of a trestle and carrying on its rails a turnover car dumper of the movable type. Beyond the car dumper runway is a return track for empty cars. The loaded cars are pushed onto the dumper by means of a locomotive, and the coal is dumped into a 100-ton hopper on the rear of the loading tower, the dumper having been brought into line with the latter. The tower hop-

per is provided with a gate, through which the coal is fed into a scraper conveyor. The latter carries the coal up a pivoted inclined boom which extends out over the boat when loading, and carries an adjustable telescopic chute at its outer end so that the coal may be directed where desired. The conveyor on the boom is the largest ever built of this type, having a capacity of 3,000 tons per hour when the boom is approximately level.

It is intended, when business warrants it, to add another loading tower so that one tower may be kept busy loading into empty hatches while the other takes an occasional car-load from the dumper for trimming hatches already partly filled. The installation is very inexpensive in first cost, compared to the bin system, and requires comparatively little power. It may be operated by one (1) 300-kw. rotary and the peak loads are not great enough to cause any noticeable flicker in the lights in the end of a 6600-volt line four or five miles long.

Turning from docks to steel plants, an interesting variation on the usual type of lifting dumper is now being installed in Eastern Ohio. With this dumper it is possible either to dump ore into transfer cars at a low level or coal into a crusher at a higher level. This is accomplished by having a removable pivot point for the low dumping position. The two notable things about this dumper are, first, that it is electrically operated (which is unique for a lifting dumper in this country); and, second, that the system of control is so arranged as to give a slow-down before the cradle strikes the active pivot point either hoisting or lowering, and also gives slow-down and power cut-off at the end of cradle rotation.

There is now nearing completion another type of dumper which is also intended to deliver material to one of two fixed points, but in this case the points are separated horizontally and not vertically. The dumper is of the turn-over, movable type so that it may travel to either position. An electric pusher is used so that the cars may be placed upon the cradle with the same facility as in the case of a stationary dumper. This machine combines the good points of both the movable and stationary types, but its horizontal travel must be restricted to reasonable limits if it is desired

to handle both the pusher and the cradle by means of the same operator.

There is a recent development along the lines of a gantry crane which the writer believes to be somewhat out of the ordinary. This piece of apparatus is for use in connection with a system of concrete tanks, each tank being about 88 ft. wide and 16 ft. deep. These tanks are filled with copper ore by means of a gantry crane containing a conveyor similar to the type of construction occasionally used with coal bridges. After a tank has been filled with ore, sulphuric acid is turned into it and the copper is leached out. The residue is then excavated by means of another gantry crane, the trolley of which is almost identical with those used on stiff-legged unloaders along the Lakes. The operator, being directly over the bucket, can work very close to the sides and the bottom of the tank without injuring the lining, which is sheet lead. Moreover, a simple mechanical limit can be used to definitely prevent overtravel when lowering the bucket. The tailings are dumped into chute which projects over the tank while the refuse is being discharged into cars. The average capacity of this machine, which has not yet been completed, is estimated at 500 tons per hour.

S. C. Coey: Some time ago, my old friend Friedlaender told me we were wrong in having flywheels and clutches on our shears, and we would be interested to hear what Mr. Friedlaender can tell us on this subject.

E. Friedlaender: In view of the fact that very little data on motor-driven shears is available, the information, derived from the operation and from special tests of a large shear in a new rail and billet mill, may prove interesting and beneficial.

The shear in mind is an 800-ton motor-driven, vertical billet shear, with motor-driven gauge and racking device. The cutting capacity of the shear ranges from six bars, 4"x4", to three bars 6"x6", thus making the cutting capacity, for which the shear was designed, 108 sq.in. Originally this machine was built for thirteen (13) cuts per minute and the shear knife was operated by means of a hydraulic clutch. The shear was driven by a 200-h.p., 3-phase, 220-volt, 475 r.p.m., phase-wound induction motor, coupled direct to a shaft carrying an 8,600-lb. flywheel, which shaft, in turn,

was coupled to the shear drive shaft through two sets of herring-bone gears.

The principle of the shear was that the motor be kept running continuously at full speed and the cutting operation be performed by means of the hydraulic clutch. However, due to the heavy weight of parts to be set in motion, this principle did not work out satisfactorily. It was then decided to change the motor application entirely, and instead of using a 475-r.p.m., continuously-running a-c motor, to install a compound-wound, d-c. motor which could be started and stopped for each cut by means of a magnetic controller, thus doing away with flywheel and clutch altogether.

Since the new mill had not reached the state of completion for rolling rails, we took a 180-h.p., d-c. motor of 100-r.p.m. from one of the tilting tables on second finishing stand for rails, and installed same on shear temporarily.

Although this motor was too light for the application, due to heavy accelerating peaks, we expected we might be able to get along with it until some better arrangement could be made.

The motor was geared through a reduction of 40 to 25, direct to the flywheel shaft, the flywheel having been removed. To operate the shear, we bolted the hydraulic clutch direct to the herringbone gear. For cutting short pieces, the motor was kept running continuously, while for longer pieces it was stopped and accelerated for each cut.

We first started the motor on full-field, with control circuit so arranged as to give dynamic braking. From the start we were able to see some possibilities ahead with the d-c. motor. We started and stopped the motor without excessive sparking or spitting at the commutator, and made the cuts in good shape, but we could only get from 7 to 8 cuts per minute, cutting short billets with motor running continuously.

Cutting at this rate would not keep the steel out of the way of the mill, so we started a series of tests, to find out just what could be done under the circumstances.

Our 180-h.p. motor, running at 100 r.p.m. with full-field, has a field current of 9.5 amperes. The first test was made by gradually weakening the field, and in turn, increasing the speed of the motor. To our delight, disregarding a

slight increase in starting peaks, the cutting peaks were decreased due to the moment of inertia of the revolving parts. We continued to decrease the field current to 3.5 amperes, which increased the speed to approximately 210 r.p.m. This enabled us to make some ten cuts per minute, despite the fact that the speed dropped very materially during the actual cutting operation. One thing we experienced with the weak field current was that we were unable to get sufficient dynamic braking to bring the shear to rest quickly enough when cutting long billets, which necessitates the stopping of motor for each cut. To overcome this difficulty, we installed a series brake on the end of the motor shaft which enables us to stop motor in time to stop blade from coming down on steel before the proper length has been set. I might state here that we even went so far as to take the shunt field off, entirely, and run motor on series field only, but we were unable to hold, or stop shear in proper position with the series brakes, at this time two brakes being installed on the end of the motor shaft.

Following this we made a very complete test on the shear with a two-fold purpose, first, to determine the proper size of motor required for the operation of shear; and second, to obtain some useful data in regard to the shearing of steel. After conducting the above tests, it was learned that the peaks in some cases would go as high as 450 h.p., depending on the number of billets and the temperature of the steel, but if a motor was installed of the size required to give 350 h.p. at 200 r.p.m., there would be sufficient power to give about 14 cuts per minute.

In conclusion I might say that as a result of the above experimenting and tests, our company has decided to purchase a 350-h.p., 220-volt, 200-r.p.m. compound-wound motor, and, in turn, the people that manufactured the shear will make some changes, eliminating entirely the hydraulic clutch and flywheel.

S. C. Coey: I think the idea is a very interesting one and it probably can be worked out in a number of cases.

I will now introduce Mr. Ward Harrison, who will give us some data on illumination.

Ward Harrison: Since the subject of illumination was last considered by this Association, no radical departures

have been made in the development of new light sources; neither have there been any decided changes in previous practice in the methods of utilizing the existing illuminants. However, several methods of lighting which were considered decidedly novel twelve months ago, have now been sufficiently well tried out to prove their merit and are deserving of mention in this discussion, for they are just now becoming standard practice. Of these, there is time to consider



Fig. 3

but three of the most important, namely, new methods as applied to office lighting, yard lighting, flood lighting.

Office Lighting: During the past year the tendency in office and drafting-room lighting, even in industrial plants, became so decidedly in favor of the use of indirect or semi-indirect units that scarcely a factory building of any pretensions is now erected in which this form of illumination is not employed in the office space. Fig 3 shows such an installation in which the best illuminating results are secured

with but a very modest investment in lighting units. The fixture itself is shown in Fig 4. It is evident also that such a fixture may be readily used to convert existing direct light-



Fig. 4



Fig. 5

ing installations to the semi-indirect form. In this instance, it is necessary to supply only the glass bowl and three-chain suspension, and attach this directly above the socket on the

existing fixture. Generally speaking, a lamp of only 50 per cent. greater energy consumption than that required for a direct lighting system need be used; the increased expenditure for energy is far more than offset by the softer and more even illumination and absence of shadows which result from the change. In this connection, a word of caution regarding the selection of glassware may not be amiss, for unless bowls of great density are chosen, the results will be but little superior to those obtained from a direct lighting system. The density of the glass should be such that the bowls are not markedly brighter than the ceiling.

Yard Lighting: The extensive use of Mazda "C" lamps in street lighting has led recently to the development

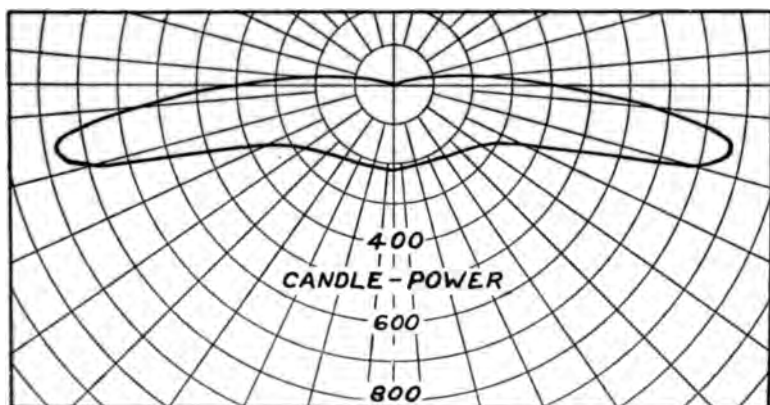


Fig. 6

of the prismatic glass refractor in which the prisms are kept free from dust by being placed on the inner surfaces of two glass bowls, which are then fastened together and made air tight. Fig. 5 shows one type of unit for outdoor service complete with refractor. A distribution curve is given in Fig. 6 for a 300-watt Mazda "C" lamp, and it will be seen that at angles near the horizontal, the intensity is nearly 900 candle-power, or fully three times the rated wattage of the lamp. Such fixtures can be used quite as effectively in yard lighting as in street illumination, for it is the light at angles near the horizontal which is most effective in illuminating distant areas and the dark corners.

Flood Lighting: The concentrated filament of the newer Mazda lamps have given us a point source of light, which makes it possible to utilize flood lighting, or projector lighting, with large units as a permanent means of illumination. The fact that when once installed, the fixtures and lamps require no more attention than the more usual forms of lighting units, represents the principal advance of the incandescent projector over the arc. On account of their adaptabil-



Fig. 7

ity, such flood lights are now being extensively employed for display or decorative lighting of which the illustration in Fig. 7 is a good example. Practically, these units are also found to fulfill a most useful purpose for temporary lighting in and about large industrial plants. For example—if repairs must be made to a gantry at night and no convenient facilities are available for obtaining electric light close at hand, a projector may be mounted in a window of a building many yards away, and the center of operations as brilliantly illuminated as if a portable cluster were used.

Aside from the question of night repair and construction work, the electrical engineer of a steel plant would to-day do well to keep on hand a number of such projectors simply from the standpoint of preparedness, for in the case of strikes or other disturbances, all approaches to a plant can be effectively lighted by a battery of units hastily put into service. In fact, the principal advantage of the flood lighting projector in industrial lighting lies in the ease and quickness with which it may be made to solve many of the difficulties which have heretofore often baffled the engineer when light is greatly needed.

DISCUSSION

S. C. Coey: Before opening the meeting for general discussion, there may be some of our members who have special devices in electrical development that they would like to bring out at this time. I have no doubt there are a number of questions we would like to ask the various speakers of this evening. Personally, I would like to know from Mr. Pauly what would happen on the iron-clad switchboard if the front of the board is pulled out while the circuit is closed, without opening the oil switch.

R. H. McLain: Mr. Pauly is not here now, but I can answer that question. It is impossible to remove the iron-clad unit front until after the oil switch has been opened.

W. O. Oschmann: How does the cost of this iron-clad switchboard compare with standard marble or slate board?

Edw. Marshall: The cost would be from 15 to 20 per cent greater than for the present day switchboard. The cost to the purchaser of the finished installation would not, perhaps, be any greater.

E. Friedlaender: If I understood correctly, Mr. Steele mentioned a reactance coil inside of a transformer as an additional safety feature to protect the transformer. I think that is rather a bad place to put a protective device. If the reactance coil blows up, the transformer would probably be damaged. I think it would be better to put the reactance coil outside of the transformer, so if anything happens to

the reactance coil it can be cut out and the transformer used; probably saving a great deal of expense and delay by spending a little more money in first cost. If you put anything up for safety, it should be separated from the article we are trying to protect.

I would like to get a little more information about the oil. As Mr. Steele has shown, we have to watch the oil closely. What oil shall we buy? Shall we go to the manufacturers of the transformers to buy the oil, or can we go out and buy it from a little concern like the Standard Oil? Will the transformer manufacturers come back and say we cannot operate our transformers with such oil? I would like to know what oil we should buy, such as to flash point, viscosity, dielectric test, etc. We wrote up transformer oil specifications four or five years ago but could not get them approved by all transformer manufacturers.

H. G. Steele: In answer to Mr. Friedlaender's first question, the reactance coils are installed inside of the transformer. Placing these coils inside of the transformer adds very little to the cost. Placing them outside of the transformer means separate case, oil, bushings and leads, and if Mr. Friedlaender or any purchaser would authorize additional expenditures for reactance coils mounted separately in their own cases, we would be very glad to supply them.

The reactance coils spoken of by the writer add but very little to the cost of the transformer and, therefore, they are an additional safety factor without additional expense to the purchaser. These reactance coils may be likened to a safety valve. The reactance coils may be burned out but the windings may be spared, whereas, the ordinary method of only extra insulating the end turns of the windings may result in the end turns being burned out, which is just as bad as if the windings were burned out. Therefore, I repeat that, while it is all right to extra insulate the end turns, these little reactance coils are an added factor of safety.

I agree with Mr. Friedlaender that a separately mounted reactance coil in its own case, apart from the transformer, would be even better, but this would also add considerably to the cost of the installation, just the same as

lightning arresters or fuses or an oil circuit breaker mounted separately from the transformer adds very much to the expense of the installation.

Replying to the suggestion that if the reactance coil mounted inside of the transformer should burn up, it might cause damage to the transformer, I wish to state that over a period of the last two years, there has not been a single case where this construction has been used that the transformer windings have been damaged from the failure of the reactance coil. On the contrary, the reactance coils have taken the shock in many cases and saved the windings. In the transformers that have burned out with reactance coils, it was a simple matter to cut around the reactance coil and go on operating until the new reactance coil was cured.

In answer to the oil question, the speaker is very willing to give you specifications of what is considered good transformer oil. It is a rather difficult task, however, to get good transformer oil and know positively that every barrel you get is up to specifications.

Oil should be Pennsylvania Crude, natural, neutral mineral oil, distilled and cold pressed to remove amorphous wax. Oil should be free from acid, alkali, sulphur and moisture, light yellow in color and free flowing.

Specifications

Flash Test 360°F.

Burn Test 420°F.

Chill Test 28°F.

Viscosity (Tagiblu at 70°F.) 84.

Dielectric Test, minimum, 30,000 volts.

Dielectric Test between 1-2" spheres 2-10" apart.

The transformer oil problem is not only a matter of getting oil—it is also a matter of handling it and preserving it after you have secured it until it is put into the transformers. Furthermore, the testing of transformer oil for electric strength varies seemingly without reason. Five tests taken on the same sample will often vary as much as 50% in voltage, but if you are able to secure good transformer oil, then the care of it before it is put into the transformers is very important.

The ordinary method of caring for this oil until it is put into the transformers is to keep it in stock in iron drums. Now, iron drums are used over and over again by the oil companies, and when drums of oil are shipped out to a buyer, particularly to central stations, they will often empty the drums and put them out in the weather, leaving the bungs out, and rain or moisture will get into the drums, rust the iron, and it is almost impossible to get every bit of rust and scale out of the drums when they are refilled.

To avoid this, the company that I represent ships in drums made specially for transformer oil. These drums are lead lined so that if moisture or rain does get in the inside of the drums, no rust will form—so again I repeat, that even though you are able to secure good transformer oil, it is also just as vital to take care of it after it is secured up until the time it is put in the transformer.

A very small amount of moisture in transformer oil is not so very important today in transformers of 22,000 volts and lower as it was years ago before the present perfection of the impregnating process for the windings. As you all know, a transformer winding that is vacuum treated and sealed up with impregnating compound forced in under pressure, makes a coil impervious to water and, therefore, a small amount of water is not nearly so dangerous as we have been led to understand in years past. It must be understood, however, that moisture in a transformer becomes more dangerous as the voltage gets higher. I am speaking now of transformers higher than 22,000 volts.

E. Friedlaender: Is the dielectric test specification for 6600 volts the same as for 22,000 volts and over?

H. G. Steele: Some transformer manufacturers carry different grades of transformer oil, varying with the voltages of the transformers for which it is used.

S. C. Coey: What effect does rust have on the oil?

H. G. Steele: Answering this question, practically, if rust is present in transformer oil, it becomes more and more dangerous to use, just as the quantity of rust increases.

The rust may get into the windings and if it happens to get in where it could cause a short circuit, the transformer might fail. If present in sufficient quantity, it

would tend to clog the oil ducts. Even a little bit of rust or dust or dirt may cause rapid heating of the transformer.

A simple test to see the presence of a substantial amount of rust, dust or dirt is to take a sample of oil from the bottom of the transformer case and allow it to rest for twenty-four hours, when the sediment, if any, will be seen in the bottom of the bottle.

An incident of oil disintegrating and causing failure of a transformer might here be mentioned, because in this instance, it was caused by the bad water supply.

A certain steel mill had water cooled transformers where the water supply was very bad. Careful reports of the temperature of the transformers were recorded daily, but these reports did not carry the facts to the electrical engineer in charge, because the attendant in charge of the transformers, upon noticing a slight increase in temperature, turned on a little more water, and day after day, when the temperature of the transformer would show an increase, the attendant speeded up the water to keep the temperature (recorded by the thermometers on top of the transformer case) down to normal.

The cause of the trouble was that the bad water in the cooling pipes caused a coating on the inside of the pipes, and this coating acted as an insulation preventing the heat from radiating from the oil through the water pipes to the flowing water. This in turn caused the oil to heat up and deposit sludge, so that the heat was not transmitted properly from the windings to the oil and thence through the water pipes to the water.

By speeding up the water, the attendant was able to keep the temperature down in the oil that was in the top of the transformer, but the oil which surrounded the windings of the transformer, which are located in the bottom of the case, was getting hotter and hotter, until finally the transformers suddenly burned out. One transformer in the bank, however, was saved by hoisting the coils out and cleaning the inside of the case and cleaning the water pipes, and it is back in service today.

E. Friedlaender: Is Pennsylvania crude oil free from paraffine?

H. G. Steele: It is not free from paraffine, but transformer oil made from Pennsylvania crude is supposed to be free from paraffine because this is one of the specifications in the manufacture of transformer oil—"cold pressed to remove amorphous wax."

E. Friedlaender: With reference to illumination, instead of talking about large units, I would like to find out whether we could not get very small portable units. The safety point is being urged very strongly in mill work and we very often have to supply light on short notice in places where we haven't any wiring, and it would probably be dangerous to install any wires on account of the heat or gas. The point comes up, why can't we use a lamp like miners use. The ones we tried proved absolutely worthless for mill work, as the candlepower was too low, being 3 c.p. at 2 volts. Why can't we get a 2-volt lamp that will give 8 or 10 c.p., if for only 2 or 3 hours.

Ward Harrison: The trouble with getting as low as 2 volts is largely in the design of lamp, that is, to get 8 or 10 c.p. with 2 volts, you would have very short thick fibre, a fraction of an inch long, to carry 4 or 5 amperes. That means it is almost impossible to get the fibre accurately coiled, so you can know whether you had a 1, 2, or 3-volt lamp. If it comes out 3, it wouldn't give much light. If you can go to 6 volts and use 3 cells, you can get almost any c.p. you want up to 30 and get it with good satisfaction. For instance, a good many of the automobile head-lights are 6-volt lights, which give 25 or 30 c.p. for that class.

E. Friedlaender: At 6 volts the lamp is too heavy. Such a portable lamp should not weigh over 8 pounds and not be a burden to a workman who has to carry it.

Ward Harrison: I know what the problem is. It is a compromise between what you can do in the way of getting a lamp that will be satisfactory and how much weight you can carry. At 6 volts, we can make a good one, at 2 it is hard to do.

E. Friedlaender: An 8 c.p. lamp at 2 volts is now being made in Europe.

Ward Harrison: We could make them readily enough, simply by taking a chance at it. That is all there is to it. We tried to make them in connection with several proposi-

tions in a one-cell battery, but we haven't found anything that the manufacturers of the battery, for instance, would consider reliable as a marketable product.

W. T. Snyder: I think you will agree that the Electrical Development Committee has presented a very interesting program. We learned a great deal. While we have a very good representation here tonight, particularly of the mill men, we should have more at these meetings. Those absent are certainly missing much that would be to their advantage. Our mill men are better represented tonight than the associate members, in proportion to the membership. We congratulate the Electrical Development Committee on the excellent program that they have presented.



STANDARDIZATION

By STANDARDIZATION COMMITTEE, A I & S.E.E.

W.T. Snyder: We must express our appreciation of the privilege and pleasure that has been ours this evening in having a joint dinner with the Pittsburgh Jovian League. We hope that the Jovians will remain, and feel free to take part in our program. We welcome you and assure you of our extreme pleasure in having you with us.

The object of the Association of Iron & Steel Electrical Engineers is the advancement of the efficient application of electricity to the iron and steel industry, and there is no feature having a more important bearing on the efficient application of electricity to the iron and steel industry than that of standardization. It has been said that standardization when carried too far, has a tendency to restrict progress and development. That may be true in a sense, but without doubt there is a lot of work to be done along the line of interchangeability in the iron and steel industry which would impose no restriction on the development and progress of electrical apparatus; in fact, this is one of the most fertile fields in which this Association has to work. We have the problem of standardization of methods and practice; generating equipment, voltages, frequency, and temperatures; apparatus, speeds, rating, dimensions, etc. There is so much work to be done along this line that, as was remarked by the Chairman of the Standardization Committee this evening, "the field is so big, we hardly know where to start." The meeting this evening will be in charge of the Standardization Committee, and will be conducted by the Chairman of that Committee, Mr. F. D. Egan.

F. D. Egan: Members of our Association, as well as members of the Jovian League, in attempting to present the

subject this evening, an effort will not be made to take up any particular subject, but rather to talk along general lines larger measures, ratings, some of the individual branches, and cover to some extent the application of control. Each speaker for the evening will present his talk before the meeting is opened for general discussion. We will first hear from Mr. F. B. Crosby of the General Electric Company.

F. B. Crosby: I have been asked to speak briefly this evening of Standardization from the viewpoint of the manufacturer. The subject is a broad one and, from many and varied personal experiences in standardizing committee work in our own company, I believe any attempt to detail methods at this time would be obviously futile.

Broadly speaking, Standardization is the ideal toward which we are slowly but surely working, sometimes with conscious effort, but quite as often with only immediate results in view; yet the goal always is the same, namely - ultimate perfection. There may be many good, and more better ways of accomplishing a given purpose, but there can be only one best way. When that way is recognized and accepted, Standardization will have been attained automatically.

Such conditions however are, I am sorry to believe, too visionary save for optimistic contemplation.

You will note I said "when recognized and accepted". These are the two great difficulties to be overcome in our efforts at Standardization and you active members of this Association share equally with the manufacturer the responsibility of hastening our arrival at the desired goal.

It is apparently a truism in economic and industrial life, as in physical life, that while perfection is beyond our attainment, there are always present progressive or reactionary tendencies to one or the other. There is no standing still; if so, stagnation and economic death will inevitably follow! We are all learning together, you operating engineers from that best of teachers - practical experience - and we, the manufacturers, from all available sources, theoretical and experimental as well as practical.

Admittedly the manufacturer is a manufacturer primarily for the purpose of increasing the industrial wealth of

the country, and at the same time for the purpose of making a reasonable profit from the operation. This applies with equal force to the manufacturer of steel as well as of electrical products. As engineers of steel-making companies, you should be as competent to discuss the question of Standardization from the viewpoint of the manufacturer quite as well as we representatives of electrical companies.

Your problem would indeed be the simpler of the two. At first glance a tabulation of the standard shapes put out by the Carnegie Steel Company, for example, would seem to meet every conceivable requirement, but it does not. And, as any one who wishes a special shape for a special purpose finds out, there are few industries in which it is more difficult to secure prompt accommodation at reasonable cost. The steel industry is of such magnitude, however, and has already standardized so large a variety of products, that rather than incur the delay and expense of developing new shapes the prospective customer usually contents himself with standard stock.

From the standpoint of development, the manufacture of steel products has reached a relatively staple condition compared with electrical products. It must be borne in mind that the short space of 15 years practically covers the general application of electricity in the manufacture of steel, and to one reasonably familiar with the more prominent variables involved, such as choice of direct or alternating current; frequency; voltage; speeds—constant, variable or adjustable; continuous or intermittent service; methods of drive—ropes, belts, gears, or direct; improvements in design based on clearer understanding of operating conditions; improvements in quality of material entering into the design, and finally, but by no means least, the individual whims and prejudices of the purchaser: When all these things are duly considered the marvel is that so much has been already accomplished toward Standardization.

In spite of the present advanced status of electrification, even such efforts towards Standardization as have been an economic necessity for the continued existence of the electrical manufacturer are often a source of dissatisfaction to the purchaser. Your personal experience will no doubt bear out my statement, that in some instances no sooner had you ad-

opted a so-called standard line of motors or control, and settled down confident of the solution of your difficulties, than you were confronted with the announcement that that particular line had been discontinued, so that from the point of Standardization you were no better provided for than before. If you think the manufacturer does this merely for his own amusement I can assure you that you are mistaken.

An analysis of facts will show in nearly every case that the new lines are brought out primarily to embody improvements which you suggest, and not as you may often suspect—solely for the purpose of cheapening our product so that we may pocket a larger profit. Sometimes your suggestions come in the form of complaints and sometimes as real constructive criticisms. I think I can honestly say that intelligent criticism of our designs or clearer explanation of your requirements are always sincerely welcomed. It often takes time and it always takes a large expenditure of money to get out a new line. Such expenditures, including designs, drawings, patterns, new tools, modified factory facilities, testing, new advertising campaigns, etc., always involve thousands and sometimes hundreds of thousands of dollars, and cannot be undertaken without most careful consideration. Furthermore, to put a new line into commercial production usually requires from a year to eighteen months. In the meantime still further possible improvements are discovered which must be held over until the next general revision is warranted, and so it continues.

Where a monopoly of design or product exists, there is no question but that Standardization of product and manufacturing methods net the manufacturer the largest profit. For a typical example of this policy carried to the N-th power, you have only to study Henry Ford's methods. Similar methods would most gladly be adopted by every electrical manufacturer in the country if you gentlemen would permit it. You would be first to oppose any agreement tacit or otherwise among electrical manufacturers which would tend to retard the truly phenomenal progress in recent electrical development which is the direct result of competitive research.

Only such products and methods as can meet unquestioned the demands of service can justly be termed standards. It seems evident therefore that the formal recognition of such standards must come about through the intelligent study of actual operating requirements and practical limitations of electrical design, but such Associations as **this one** and others of similar character.

Much credit is due for the excellent work already accomplished along this line by the Standardization Committee of the American Institute of Electrical Engineers and by the Power Club in proposing certain standards for materials, methods of testing, and rating machines, etc. For the specific benefit of your own industry, however, much remains to be done which you only can do for yourselves in co-operation with the electrical manufacturers.

In discussing this subject with members of this Association, I have found it necessary to define my position. In the first place I believe it should be clearly understood that any action taken by your Committee on Standardization and formally approved by the Association is not in any sense binding upon individual members. I have found objection to this, based on the erroneous idea that any such standardization would be binding. That is not my understanding at all; neither do I think it is the understanding of your committee. It should take the form of suggestions or recommendations embodying the consensus of opinion relative to methods of accomplishing certain results. In event of anything approaching an even division of opinion, alternative suggestions should be incorporated.

If the Association is to accomplish its real purpose of mutual assistance among its members and the general advancement of the art of electrification, then the experience and advice of those members fortunate enough to be in the employ of the more progressive companies should be available for the guidance of those younger or less happily situated.

To my mind, one of the most efficient means of bringing this about would be the compilation in pamphlet form of the approved recommendations of your committee on general practice. These might be issued from time to time in uniform size for insertion in a loose leaf binder.

Above all, these suggestions should be non-partisan and absolutely independent of commercial bias. I cannot emphasize my views on that point too strongly. If this is to be successfully carried out, we must get away from anything that would tend to reflect directly or indirectly on any one manufacturer, either to their advantage or disadvantage. We must keep in mind solely that which would work to the greatest advantage of your own industry. Names of manufacturers should not appear, nor should the recommendations be of such character as to exclude any competitive equipment unless adequate reasons are approved by the Association. These recommendations should not be confined to existing practice. If there is a real demand from the majority of the Association for apparatus, methods of control, or safety devices, not on the market, such a demand backed by the Association in its formal recommendations would have far more weight with the manufacturer than if coming from isolated individuals.

The manufacturers would undoubtedly, and I believe justly, object to any tendency in these recommendations to dictate details of design, for that would surely exceed the jurisdiction of your committee. There is a clear distinction between suggesting desirable results and arbitrarily specifying the manner in which those results shall be obtained.

Mill builders and gear builders should be consulted and improvements permitting the use of higher motor speeds considered.

Investigations of existing flywheels and their speed torque relations to gears, motors and control should be brought out.

The question of "safe" maximum voltage about the mill is one also frequently raised.

It is a delicate subject, but perhaps not wholly improper to suggest, that one of the functions of this Committee be that of a clearing house for complaints on defective apparatus. Here again the greatest care should be taken not to use manufacturers' names or even to implicate them by detailed description of the defective equipment. My idea would be merely to call to the attention of your members

the possibility of weakness at given points in order that they might satisfy themselves before purchasing. Such a systematic study of operating troubles, and an intelligent differentiation between sporadic cases due to local causes and those showing inherent weakness in design, would, I believe, confer a great benefit upon your members and at the same time would prove a powerful incentive toward **standardization of quality** at least on the part of the manufacturer.

There is very much more which could be said on this subject but in conclusion may I state that I have discussed this matter thoroughly with the Chairman of the Standardization Committee of our company and I believe I am expressing his opinion as well as my own firm convictions when I say that any effective movement toward standardization of electrification of steel plants must originate through the concerted action of operating engineers rather than among the manufacturers. Upon evidence of such concerted action in good faith, our company stands ready to co-operate to the fullest degree.

F. D. Egan: In reference to standardization as regards tests, it has not been the practice among iron and steel engineers to follow any detail; in other words, the specifications call for all tests to follow the practice of the A.I. of E.E. There have been special cases that called for machines, particularly in the larger drives for lower temperature guarantees at normal rating. A few years ago, it was almost believed to be necessary that all machines be designed at that low rate. Mr. Brent Wiley of the Westinghouse Electric & Manufacturing Company will give his views in regard to speed and temperature guarantees.

Brent Wiley: One of the subjects of standardization that is receiving the attention of a number of electrical societies is that of rating of apparatus including generators, transformers and motors. At the present the usual rating is 40°C. rise for full load continuously—125 per cent. load—2 hrs.—50° C. rise. The tendency is towards a single rating which is based on a conservative temperature rise for full load continuously. The temperature ranges from 50° C. to 55° C. rise and no overload rating is given.

In the case of large mill motors, it is customary to insulate the winding with a type of insulation which will with-

stand an actual temperature of 105° C. without undue deterioration. Then, considering an air temperature of 35° C. which is higher than the average, and a rise of 50° C. thermometer, and 15° C. for internal drops, we still have some margin for continuous full-load running. With air temperatures below 35° C. the margin for extra load is still greater.

A machine is designed with certain copper and iron losses which are usually plotted in curve form. These curves are not parallel and as a rule have only one point in common which determines the most efficient rating for the design in question.

The user is most concerned with the safe limit working capacity of the motor and is therefore, most interested in the performance at this point. If, however, it is necessary to include guarantees on a lower temperature rise basis, then the designer is handicapped in the proportioning of the materials, and as a rule has to specify an extra amount of either copper or iron without actually increasing the real working capacity of the unit.

In the past there has been two factors of uncertainty which have prompted the wise precaution of extra capacity in the mill driving unit. First, on account of the limited data available the actual power required to roll steel was not very definitely understood and methods of calculation not developed. Second, experience had shown that practically every mill has certain possibilities regarding the development of increased capacity, due to changes of mill design and method of operation as best determined after the mill has been put in regular service.

By July 1917 there will be installed over 300 large main roll equipments, totalling approximately 500,000 horse power. Experience with a majority of these units covers an average period of five years and much has been learned by the steel companies and electrical manufacturers regarding power requirements. This knowledge tends to eliminate the first factor of uncertainty as mentioned above, which in the past has meant extra capacity of driving unit. The remaining factor, namely the mill possibilities, will be governed in many cases by conditions which will give a fairly definite limit to its probable increased capacity. Thus, today the proper selection of motor size is not such a problem, and the

percentage of extra capacity to provide can be made on a practical basis. This may be done by specifying a motor of low temperature rise for full load continuously—which machine will be capable of twenty-five to thirty-five per cent. overload continuously without undue deterioration, or a motor of greater horse power rating at the safe working capacity as outlined for single rating machine can be selected. The latter is preferable and will result in a lower first cost and better economy of operation.

There is one particular point I would like to mention in regard to small motors, which a number of members have adopted and are carrying out in practice as far as possible; that is, the method of connecting the motor to the driven machine. A great many of the applications in the steel industry require that the motor be geared. If the motor instead of being geared direct, is coupled through a flexible coupling, with separate shaft mounted between two bearings, it will eliminate three-fourths of the mechanical and electrical troubles. The question of insulation has been improved very materially in the last several years, and if vibration and shocks are decreased an appreciable amount, the life of the apparatus will be lengthened considerably.

F. D. Egan: Mr. Wiley brought up the question: In the past when ordering motors for large mill drives, due to lack of information, the steel mill electrical engineer was almost compelled, after attempting to get a load curve, to purchase a motor at a normal rating that would possibly cover the mill speeds, or calculated power curve for the motor furnished by the purchaser giving normal rating at 35° rise. In the majority of cases, after these motors were installed, it has been found, except in a few cases, that motors were entirely too large. Since then, any amount of testing information has been developed, and today the tendency is to buy a motor single rating rather than multiple rating, which differs from the past in plants where we had no experience in regard to rolling mill duty.

H. F. Stratton (read by H. J. Fisher): Standardization is making different things as much alike as possible.

Without doubt, many people want more standardization. Various technical societies appoint committees to consider and recommend the adoption of certain standards. Operat-

ing men in factories and mills are continually alert to standardize machinery which they use. Purchasing agents in sending out specifications are, in reality, adopting certain standards to which bidders must conform. The manufacturer of equipment made and sold in quantities, adopts a standard when he makes his designs and he changes this standard with great reluctance.

Men in all departments of manufacturing—the designer, the builder, the buyer and the user—all appreciate the benefits of standardization. Is it true, however, that they desire standardization for the same reasons, and if they do not, where do their interests conflict?

In the case of the operating man, the man who really uses machinery, it is easy to see some of the reasons why he insists on standardization. Interchangeability is a big factor. For instance, railroad equipment must be standardized in order that cars may be switched on to different tracks or made up into trains. In the factory, more particularly in the steel mill, wearing parts should be interchangeable as much as possible, to prevent stocking an excessive amount of spare parts and to reduce the delays and vexations of replacing worn out or broken parts.

Standardization of connections of electrical machines, of methods of control or of the general features of electrical design, is valuable, because the electrical department can then become thoroughly familiar with these broad principles. Standardization of terminal markings on electrical apparatus, of symbols used to designate certain parts of electrical equipment, of abbreviations and definitions of electrical terms, all these, if standardized, are more easily learned and understood.

The purchasing agent, or the operating men when temporarily acting in a purchasing capacity, is interested in standardization in order that different bidders may quote, as far as possible, on equivalent machinery.

The manufacturer of electrical machinery is keenly interested in the standards which he himself has adopted. After a manufacturer has sold machines of any specific design, he must be prepared to furnish spare parts for this machine for many years, even though he should radically change his designs. Unless real benefit is gained, the manu-

facturer dislikes to change his designs, because by so doing he must immediately shoulder the expense of new stock, tools and jigs, and other manufacturing equipment. The manufacturer also appreciates that the interchangeability of his product is necessary in order that it may be sold successfully in competition.

The manufacturer, the buyer and the user, all have something to gain from standardization, but perhaps they would not standardize the same things in the same ways. I suggest that we consider some of the different phases of standardization and try to see where the manufacturer, the buyer and the user can agree,

If we consider the interchangeability of electrical equipment, we must agree that it is impossible to standardize the dimensions of the wearing parts of electrical equipment, manufactured by different companies, to the extent that they will be interchangeable. Some time, far in the future, this may be possible, but at present the expense and confusion of such a change would be prohibitive. When it happens that the tapers on the shaft extensions of mill motors, manufactured by different companies, are not the same, we cannot hope to see interchangeability in the many small and complicated parts of the electrical equipment manufactured by different companies.

If we consider the standardization of terminal markings, symbols, definitions, abbreviations, and all other terms relating to electrical machinery, it seems that no honest objection can be offered to this, by the manufacturer, the buyer or the user. This kind of standardization means the forming of a language clearly and uniformly understood by all persons interested in it. It would mean less misunderstanding; it would make it easier to build up a technical literature in a field which at present needs it badly; and in the case of the young men who are starting in either the manufacturing or the operating end, it would greatly help towards a clear and rapid understanding of their business. I can see no valid objection to standardizing terminals, symbols, abbreviations, etc., other than the minor inconveniences which people would suffer in abandoning some of their own local terms and conforming to whatever standard should be adopted.

The question arises as to who should undertake the responsibility of this standardization. No better organization could be selected than the Association of Iron & Steel Electrical Engineers, composed as it is of men representing both manufacturing and operating, and all of them honestly appreciative of the benefits to be gained. The American Institute of Electrical Engineers, The National Electric Light Association, and the Electric Power Club have all worked along these lines. In the case of these organizations, the matter has been painstakingly studied, and I think that the Association of Iron & Steel Electrical Engineers should collaborate with the efforts of the other organizations, rather than act independently of them. I suggest, therefore, the appointment of a committee or sub-committee, to confer with any other technical organizations engaged in standardization of electrical equipment.

Another phase of standardization is to rate the capacity of electrical machinery by some standard such as temperature rise. The buyer can use such ratings, because to a certain extent equipment furnished under standardized ratings would be equally good and the buyer free to place the order from the standpoint of price, delivery, service or some other consideration. The honest manufacturer would not object to standardized ratings if they can be made to really indicate the acceptability of the equipment for the work actually to be done. The trouble is that such ratings often get on the basis of irrelevant standards. To illustrate, if some cast grid resistances were to be furnished to carry 100 amperes continuously, a good specification would be that its ultimate temperature should not exceed 250° C. On the other hand, if resistances were wanted for a 25 h.p. controller, it would not necessarily be a good specification that this should have a continuous capacity of 60 amperes, because some resistance would be much better suited to carry 100 amperes intermittently than another resistance, although both resistances might carry 60 amperes continuously with equal satisfaction.

As another illustration take the case of motors which have their temperature rise standardized. I have never made motors, but I have bought them and I know that some makes of motors are much better than other makes, al-

though the standardized temperature rise in each case is the same. Another difficulty is that different large buyers have very different ideas about ratings of electrical equipment, and the peculiarity is that each may be right for his own mill. Probably some work can be done in standardizing ratings of electrical machinery, but these efforts should be cautious. To go too far at once along such lines, would be to invite disregard of standardized ratings.

It has been often proposed to standardize methods of systems. An illustration of this would be to designate the current values and number of accelerating steps in an automatic motor starter of a certain size. The condition at present in such matters is chaotic. Not only different users, but different manufacturers have different standards. The same person may vary his ideas from one year to another, because of changing requirements or improvement in the equipment. Sometimes the purchaser places more importance on satisfactory service over a long period of years and sometimes he is more interested in a lower purchase price. Who shall say which point of view is right? My personal opinion is that the standardizing of systems or methods should not be undertaken until common practice has, by its own action, substantially reached a standard on which the great majority of both users and manufacturers can agree.

No one objects to attempting the standardization of electrical equipment from the standpoint of safety. This matter is better understood by the users than by the manufacturers, and no manufacturer wishes to disregard the requirements for safety as determined by the operating men. It is, however, expensive and burdensome to the manufacturer to change his design to conform to safety requirements, if the same design is not satisfactory to different purchasers or if the manufacturer cannot know that all competitors will be made to toe the mark.

I want to argue that it is less reasonable to standardize mill equipment than ordinary factory or power house equipment. As illustrations, consider an overhead crane in a machine shop, the generator in a power house, or a motor driven lathe. Each of these has substantially the same work to do day after day, and even the extra or surplus work which may be demanded of it is well known. Standards in-

dicating fairly accurately the acceptability of such equipment. On the other hand, what is it that governs the acceptability of mill equipment? Is it not its ability to keep on operating satisfactorily under unexpected conditions? The successful manufacturers of mill equipment, design to meet emergencies rather than average conditions. You cannot standardize emergencies, and that is one reason why it is difficult to standardize mill equipment on any basis which really indicates its acceptability.

I have heard it argued that standardization should be as inclusive as possible to give the smaller steel mills or the less experienced operating men the benefit of what the larger mills and the more skilled and experienced operating men have found to be preferable. This distribution of information is excellent, but should it not be in technical papers rather than in standards adopted by this Association?

I hope the Association will proceed with standardization only as fast as it will be accepted and used. Is it not true that years ago this Association wrote complete specifications for cranes which have not been followed, and is it also not true that one of the large steel companies printed safety specifications which are not universally followed by its own mills? If you standardize too rapidly, the standards are not followed, and I take it that nobody wants to standardize unless you accomplish something.

In conclusion, my argument is that the Association standardize on terms, symbols, abbreviations, terminal markings, etc., in collaboration with the American Institute of Electrical Engineers, the National Electric Light Association, and the Electrical Power Club. When these standards are adopted and used universally, then the Association should proceed to the more debatable questions and standardize as rapidly as people will use the standards.

C. T. Henderson: The real distinction between the manner in which an engineer and an ordinary layman attacks a problem is that the engineer generally looks around to see what someone else has done and the layman generally goes ahead on his own responsibility. It is my feeling that this Association in attempting a line of standardization work should follow what I consider to be good engineering practice; that is to say before attempting any such work they

should make a definite and whole-hearted attempt to find out what other associations and clubs have done. We have, as has been mentioned this evening, the American Institute of Electrical Engineers, which has adopted standardization rules covering ratings for apparatus, tests for its insulation and similar points. We have the Master Car Builders Association, which has taken the steps necessary to make railway equipment interchangeable. We have the Society of Automobile Engineers, which has done a great deal of wonderful work in the standardization of parts for automobiles. This Society has gone so far as to adopt a standard line of dimensions for car parts, such as carburetors, magnetos, etc., and all of these standards help them in their work. They help them to buy quickly and buy cheaply. The Power Club has also done a great deal of work. Some of its work has been mentioned previously this evening. I feel that the Power Club is working along a line more nearly parallel to that which should be followed by this Association than any of the other organizations mentioned. The Power Club, for example, has standardized a line of nomenclature for connection diagrams and standardized on motor and controller terminal markings. On the other hand, I know that in our business we do not follow these nomenclature standards as closely for steel mill apparatus as we should, because they are not complete enough to cover all steel mill conditions, and because there is not a demand among steel mill men that these standards be followed. The Power Club has likewise standardized on motor speeds. A few years ago, the man who manufactured a machine driven by a small motor—say 1-20 to 1-2 h.p.—had to almost redesign his machine if he wanted to change from a-c. to d-c. drive, because such a change was almost sure to mean different motor dimensions and speed. If you look over manufacturers catalogues today, however, you will find that direct current motors of fractional horse power are designed for the same speed as alternating current motors of the same capacity. I believe that in many cases the standardization has been carried to such a point as to establish a standard for the center line height of certain small motor shafts. This is a point that might not be a bad thing for you members of the Associa-

tion of Iron & Steel Electrical Engineers to consider in connection with mill motors.

In reviewing the whole situation, it seems to me that it is absolutely impossible for this Association to standardize control equipment to such an extent that parts of equipment manufactured by different concerns will be interchangeable. I do not believe that it will be possible for the Association to do anything other than standardize its requirements. In other words, establish gauges by which the relative value of those switches which constitute a magnetic control, for example, may be determined. In the present state of the trade, it is just about as hard to tell which controller is the better of two as it used to be to determine motor values when one bidder's 15 h.p. machine would carry 25 h.p. continuously and another's would barely operate under full load without burning out. In buying under these conditions, the purchaser had to put his entire faith in the man with whom he dealt. Today the element of faith is still an important one, but only as regards points other than temperature rise.

At this particular time, the standardization of requirements in the controller line would mean a great deal to members of this Association. It would mean, for example, that the controller manufacturer, instead of being in the embarrassing position of seeking material in an abnormal market in order to fill his orders, would have his shelves loaded with standard apparatus which could be purchased more cheaply and delivered more quickly than the unstandardized apparatus which is at present being produced. The average purchaser of electrical equipment does not, in my opinion, realize the cost of making such special apparatus. If the special equipment manufactured by controller builders was made to bear the overhead expense which is really directly chargeable against that equipment, its price would be prohibitively high. It is only because such overhead is spread over the entire line of apparatus produced that the price of special equipment comes at all within reason. Even a little bit of standardization will mean a considerable saving in cost of production, and the manufacturer of equipment will, I am sure, be very glad indeed to give the direct benefit of such saving to the purchaser rather than put it in his own pocket, **because while he gives you the direct saving that is effect-**

ed by the manufacture of standard rather than special apparatus, he does not necessarily give you the indirect saving that he is able to make on account of the greater volume of apparatus he can turn out in his shop in a year because of his product being standardized to at least a reasonable extent.

Some people here this evening have spoken of the desirability of drawing a specification that would cover steel mill conditions. Such a specification would undoubtedly be useful, but cannot, in my opinion, be made to fully cover all conditions. In other words, I am sure that even with such a specification in existence you men will still be compelled to use your own judgment to a large extent and to make certain departures from your specifications when buying. About the only people who do buy under rigid specifications, from which they will under no condition depart, is the U. S. Government. The U. S. Navy Department's attempts to do this in making its purchases have been rather amusing to me. I have followed them for a good many years, and, according to my observations, they no longer draw their specifications to cover what they want, but to exclude what they do not want. For example, the Navy Department asks for bids on certain machinery, and on account of his being the low bidder the job goes to a contractor who is inclined to trim the contract just as closely as he can, he will probably, under these conditions, supply the U. S. Navy Department with something they do not like, and then they will get together and redraft their specifications so that the sort of work this unsatisfactory contractor has done will be excluded in the future, and so I say they draw their specifications to exclude what they don't want rather than to cover what they do want. I imagine that if you try to draw rigid specifications covering all of your requirements and try to adhere literally to such specifications in making your purchases, you may find yourselves confronted with somewhat the same problem as the Navy Department has solved in the manner described.

I will conclude my remarks on the subject by saying that so far as the controller end of the business stands today, the purchaser appears to me to be in the position of the man who is trying to measure something without anything

to measure by. He is like the man who attempts to measure distance without even a 12" rule. He is guessing all the time. If you men will get together and formulate some gauge for the comparison of apparatus, it will help the manufacturer and will help you. It will help you by getting you better service, quicker deliveries and lower prices.

DISCUSSION

E. Friedlaender: I do not agree altogether with the speakers tonight. I am sure we men in the mills are perfectly willing to make everything standard if we know where to buy standard machinery. I think it is mostly up to the manufacturers to get together and standardize their apparatus. This has been done with the incandescent lamp—although there are many different makes on the market, all lamps are standardized as regards sizes, voltages, shapes, etc.

It is competition that works greatly against standardization; special features often make good talking points. We are ready to get together and standardize our requirements as much as possible, but are the manufacturers willing to change their designs. At present we have trouble in getting what we need, and are only too willing to take anything we can get.

W. T. Snyder: I agree with Mr. Friedlaender to a certain extent. There is undoubtedly a great deal that the manufacturers could do if they would get together on steel mill apparatus, just as some of them have done in other lines of equipment as mentioned by Mr. Henderson. On the other hand, in view of the fact that they are not doing this, the members of this Association should interest themselves enough to get together and tell the manufacturers what they would like to have, and as Mr. Crosby pointed out, they would be only too willing to do their part. The manufacturers have not reached the point where they are willing to get together to meet our ideal. We are organized for the purpose of making things as near ideal for ourselves as we can,

but we do not seem to display the proper interest to bring about the desired result.

Mr. Fisher brought up the old question of what the purchasing agent would do after the manufacturer turns out a good line of apparatus—that the purchasing agent buys the lowest priced apparatus. That is our own fault to a certain extent. The purchasing agent has only the views and recommendations of the plant engineer placed alongside the views and recommendations of the manufacturer's engineer, and he may believe that the manufacturer is more familiar with his subject than is the man at the plant. On the other hand, if the man at the plant can say: "This is what the Association of Iron & Steel Electrical Engineers recommend, what a majority of the members have found by experience, or in their judgment, to be the best to use for this particular purpose," the purchasing agent will not go against that recommendation as often as he now does.

Mr. Wiley brought out a very interesting and important point in regard to standardizing motor connections and this is one that our Association should go on record as recommending in regard to motor connections, that is, not place a pinion on the motor shaft above a certain size and speed. Such a recommendation backed by this organization would have a great deal of weight and do a great deal of good.

As pointed out by Mr. Crosby, the Standardization Committee should keep in mind that their recommendations should in no way bear any commercial reflections; names should not be used in describing apparatus, to the detriment, or advancement of any manufacturer. We must do these things from the standpoint of representations of the iron and steel industry, making general recommendations, giving no commercial advantage to any particular manufacturers, but giving all a fair chance to take care of themselves.

As remarked by one of the previous speakers, the Standardization Committee could be a medium for the distribution of information, a clearing house for complaints. There is much work that could be done by the members to make the Association worth while to create interest in the Association and enthusiasm in the members; we should all want to help. As things are now, many members are lag-

ing back, waiting until somebody gets something started. I would like to see our Standardization Committee start on this work and stick to it until it gets something definite; accomplish one thing at a time; get it in some definite form where it will be of some benefit to the Association, and incidentally, to the manufacturers.

Reference was made to crane standards drawn up a few years ago. There is no question but what those crane standards were of great benefit to users of electric cranes. We all remember the old cranes that we used to have to cut rivets to remove a line shaft, etc. The demand from the members of this Association had nearly all to do with the present high state of the design and construction of overhead cranes. We want to claim credit for it, and don't want anyone to insinuate that nothing has been done along that line. We know that some members do not follow the specifications as closely as they might. No specifications can be drawn and considered iron-bound specifications. There will be some things that will not be satisfactory to all purchasers. But take this crane standard as a whole, it is pretty well lived up to by the iron and steel industry.

Mr. Henderson suggested that our committee find out what other Associations have been doing on Standardization. I do not know whether they have done this or not, but it is one of the first things the Standardization Committee should do. There is too much work to be done to waste time and effort in going over the same ground that has been covered by other committees, and other organizations. We should weed out, and use as a basis for our work, what has been accomplished by the Power Club and other such Associations that have given these things their attention and have perhaps done better than we could do ourselves.

Mr. Henderson admits that the company he represents has not followed standardization in the iron and steel industry as much as it has in other industries. We should take that as an indictment on ourselves. If we sit back growling and complaining that the manufacturers do not do for us what they do for others, it is because there is not the demand. There is a demand from us, but it is not in concerted form. We are sitting back growling about this and about that. We will never get anywhere by that kind of

work, nor unless we get our ideas in proper form and carry the approval and recommendation of our Association. When you get them in that shape, you will get the treatment from manufacturers that you demand.

Mr. Henderson referred to the Navy Department specifying what they don't want. On some items that plan would work well, but for instance on electric cranes we would specify that we wanted steel castings, rather than enumerate the materials that we did not want. There are other similar instances where it is easier to specify what is wanted rather than what is not wanted.

While I have the floor I want to talk a little along the line that Mr. Terry did to the Jovians this evening. Our Active members are not well enough represented at these meetings. The steel mill men should consider it part of their job to attend these meetings. There is not a steel man that attends one of these meetings without taking away something with him that will repay him many times for the small amount of trouble and inconvenience that he was put to in order to be present. We should all be interested enough to attend, and for those who are not sufficiently interested, I am inclined to criticize their plant management for not insisting that they do attend, because while the individual is the loser, the plant loses the real money. There have been suggestions made at all these Pittsburgh meetings that would mean a saving in real money to the plants whose members were not represented at the meetings. Then, again, we are all losers because we do not get the benefit of the ideas and experience of the absent members who should unselfishly exchange their views and experiences with their fellow members. I would like to ask the members that are here to appoint themselves a committee of one to try to interest the members that are not attending these meetings. Try to get them here and get their views, and get their ideas of what they do want. You can accomplish nothing by staying at home and criticizing this and that, but you can get what you want if you come here and listen and take part in these discussions, and say just what it is that you do not like. In most cases the men that are not here, are the men that are growling the most back at the plant.

C. T. Henderson: While the idea is fresh in my mind from hearing Mr. Snyder's talk, I want to point out to you people, especially you active members, that there is not the same incentive for the manufacturers to get together and standardize that there is for the operating engineers to get together and demand that standards be made. It is up to you to demand those things that will help you in your work. I can remember some ten or twelve years ago when you men were working even harder than you are now, for the reason that there was not available a proper motor for steel mill work. All of you were using street railway motors "adapted" to mill work, and they were not suitable for the purpose. You got together and demanded a better motor, and what was the result?—the mill type motor today. If you had waited for someone else to bring that about you probably would not have gotten it as soon, and possibly would not have gotten it at all. It is only when you get together and demand those things your experiences shows you need you really get results.

Jas. Farrington: If the manufacturers would build both a-c. and d-c. motors with back-axle shafts; standardize those shafts with standard gear and pinion as in railway work, it would assist the interchangeability of motors.

I would like to see the manufacturers agree on that. I would like to hear what they have to say against some such arrangement; and also to allow for interchangeability of motors by using a sub-base. Take four or five of the large manufacturers, the heights of their motors are often the same size, or nearly so. On some new work we put in, we found by using a sub-base and having the manufacturer of the machine supply it, that we could use four different manufacturers' motors. This became necessary, owing to present conditions in not being able to standardize on one type of motor, and being compelled to buy from two or three firms.

F. D. Egan: Regarding motors, I feel that Mr. Snyder has presented my views to a great extent. One point he brought up regarding gear and pinion. I had some experience in purchasing a lot of cranes and found, after operating a number of years, that we are not ourselves specifying clearly what motor pinion is geared to. The buyers are specifying nothing on shaft sizes, or have a standard gear;

but we will pay a man to specify the speed at which a crane will run, but have not specified the capacity of motor. The result is that we will get possibly one size gear in one case, and in another case it will be changed.

H. J. Sage: After a long absence from this city I am glad to be with you tonight. I have been very much interested in the remarks of Mr. Henderson about mill motors. Prior to 1905 there was a great demand from the electrical engineers of the steel companies for the rugged mill type motor. Our company had considered building a mill motor but it had been practically impossible for us to obtain the necessary data to intelligently design them. About 1905, just prior to the forming of this Association upon consulting a number of electrical engineers of the steel companies, we were very glad to learn that their ideas of what was required of these mill motors was more definite, as far as capacities, speeds, size of shafts and other general characteristics of the motors were concerned. We were surprised and gratified to learn that all of the men wanted practically the same thing; there was not a 10 per cent. variation in the requirements of any of the men. With such data before us it was comparatively easy to design and manufacture what is now known as the modern mill motor, and I feel safe in saying that no motor has even been designed which is better adapted to the work it performs. This is due, I think, to the fact that all of you men had practically agreed upon what you wanted. If you can arrive at the same agreement along other lines in the electrical field, I am sure that you will have no trouble in obtaining as satisfactory results. It does not seem to me that it is the province of the Association of Iron and Steel Electrical Engineers, to go into the minor details of design of motors, generators and transformers, but you should confine your recommendations, insofar as possible, to what you desire to accomplish and leave it to the engineers of the manufacturing electrical companies to build apparatus which will meet your requirements. If among yourselves you will agree as to what you want, I think and know that the electrical companies will be only too glad to meet you more than half way.

Jas. R. Downs: It is needless to say that the remarks that have been made this evening have been exceedingly in-

teresting. They have been made, of course, by men that are spending all their time in steel mills; men that are face to face every day with questions that are, in many cases, new. The thing that keeps going through my mind in regard to this question of standardization is whether or not many of the features that you have now are not due more to the salesman's wits in attempting to sell the product of his company than it has been either on the part of his principles, or on your part; and during the early part of this discussion, I was thinking of the point that has been brought up by Mr. Sage. I have always thought that was one of the finest things that ever went through, not only in the steel mill game, but in any game. I think that was an exceedingly clever thing, because I had the pleasure of going over a set of specifications with a blanket space left in them, that was sent out by Mr. Sage's company, and I was watching that game at that time very closely, and I think Mr. Sage has said a whole lot when he said, "If you will get together yourselves and outline what you want, the motor manufacturer will be more than glad to meet you half way."

E. Friedlaender: I would like to call attention to the fact that the mill motor is not a standard motor; you will find it is a long way from being standard. We are often inconvenienced by it when laying out foundations, gearings, bedplates, etc. for mill motors. If we provide for Westinghouse motors, neither Crocker-Wheeler nor General Electric motors would fit the machinery—heights, lengths, shafts, gearings, etc. are different; nothing is standardized. The manufacturers had a good chance to get together and standardize these details, but they overlooked it.

E. Chesrown: I have been interested in several features of the discussion, as well as Mr. Crosby's admirable talk on standardization, and some features strike me as requiring considerable further consideration. For example, the question of this Association adopting standards is one which it seems to me is an excellent thing. I know when the company I was then connected with brought out their mill motor, the question of standardizing the axle diameters and other features was brought up, and some of the prominent engineers in the steel industry insisted on the largest diameters which were then possible with existing designs.

The motors were made to suit those diameters and it was necessary to modify practically all of them on the first order.

Now another feature is the question of this Association adopting standards for various sorts of service. That might be practicable to a considerable extent on a mill motor. We find a line of considerably standardized service; the mill tables, screwdowns and cranes, cover very largely the field to which these motors are applied. Now another feature enters, in that this Association is composed of a large number of individuals with separate and distinct experience. A man for instance, in a sheet mill has a different line of experience to that of a man in a blooming mill, incidentally, his idea would be different. On the other hand, manufacturers have a clearing house for this information, such as has been suggested, and they are in position to accurately tabulate and disseminate this information; and, as Mr. Friedlaender says, are in a position to recommend standards which cover a broader experience than any individuals. The consensus of opinion in this organization would be largely that of the most active and interested members only.

It seems to me that standardization can only be carried to a moderate degree of limitation. The question of temperatures can be determined. I am referring now to heavier service. Questions of efficiency, performance, and on alternating current motors, the power factor, etc., but whatever that standard may be, it should mean only one specific thing. For instance, if a single rating is adopted, at higher temperature, it means a smaller motor than if a lower temperature is adopted, and if equivalent ratings are required they can be secured at a largely increased expense. This does not hold entirely true, because a motor designed with a lower temperature will have different characteristics than one designed for the higher temperature rating.

On control, of which a large percentage is applied to mill motors, it ought to be equal on the number of switches, accelerating steps, interlocks, double or single pole protection, etc., on motors for mill tables, screw downs and cranes. A certain number of steps between 25 and 50 h.p.; 25 being about the limit for automatic control; another for 50 to 75 and so on. That is about as far as they can go, because of their individual designs which they must adopt. But it

would certainly enable manufacturers to standardize on the number of parts, and purchasers could buy standard stock for shipment, and consequently secure more prompt delivery and a lower price.

It would be interesting to take a vote by ballot on some particular selected feature of standardization, and have the Standardization Committee carry this to the extent of completing correspondence; in other words, insist on some way of getting the expression of all individual members, then tabulate these, and see how near a standard can be worked out for this feature. I think you would need two or three standards to cover the requirements in the organization. That, of course, means no standard, and until the minority members are willing to accept as good engineering, the opinions of the majority in the organization, it seems to me standardization is a considerable distance away, but that does not make it the less desirable for the Standardization Committee to get into co-operation with the manufacturers.

L. F. Galbreath: In view of the fact that this meeting is called for the purpose of going into the matter of standardization, I think it would be well to consider the rating of motors on their commutating capacity, as well as giving them a heat rating. I think it would also be advisable to consider the designing cotton insulated crane rated motors to take fire-proof insulation in order to raise the continuous rating of the motor nearer to its commutating capacity. This would give us a very efficient mill rated motor without any change in the mechanical parts. It would also be a good crane motor, where the room temperature is high, as the fire-proof insulation would be just as reliable at a temperature of 25 degrees Centigrade higher than the cotton insulation.

Another step towards standardization would be to design the motor as a totally enclosed ventilated motor. This would give us an opportunity of choosing our ventilating air, also permit the use of the motors in hot and dirty places. If the motor is properly designed for self-ventilation, the hot point temperature can be reduced, which would make a more flexible and reliable motor.

A. G. Pierce: One point in connection with standardization, it seems to me, is that electrical material, in a way,

does not fall in the same classification with other components of the mill. The average life of electrical material specified and supplied is less than other material. This seems to be accepted as a fixed condition. Why should there be one life standard for electrical material, and another life standard for other parts of the mill? What is the proper ideal to which we should aim in this respect?

W. Greenwood: I do not know why I should be called on to enter the discussion. I must say that I agree with every speaker that has spoken here tonight, in their main utterances, the substance of which is, you can standardize if you will and you can't if you will not; you should and you should not. It seems to me that in this discussion, the speakers have brought out the fact that they have an ideal in mind, or they think an ideal can be attained, but it is put on the other fellow to prescribe the ideal. It has been remarked that railroads have adopted standards extensively, and that the Car Builders Association have agreed to standardize. You must not forget that in these instances there are conditions that differ materially from the conditions that exist in any kind of manufacture. The railroads are so many separate organizations, but their equipment must be interchangeable from the necessities of efficiency. Their tracks must be standard, and the equipment must be so standardized that the equipment of one unit can be used on another unit. The conditions are nowise parallel in mill work. If the standardization had been carried to its fullest extent, they would have included locomotives and all other equipment besides the car coupler and rail. You can almost count on your fingers the parts that are entirely interchangeable.

There is no denying that conditions for both manufacturer and users of equipment, would be much improved by standardizing some parts. For instance, as was suggested by one speaker, the height of shaft line and the dimensions of shaft, to permit of interchange of motors of similar capacity or for similar requirements. It does not seem practicable nor possible to standardize every particular feature in electrical equipment, as a difference in characteristics is just as important in many instances as is capacity and

dimensions. Further, complete standardization would tend to destroy incentive for higher development.

F. D. Egan: One thing has been discussed a great deal, that is the mill motor. When you consider starting with the building of a plant, a question that arises, you might say, from the blast furnace to the finishing mill or the finished product, is the mill motor. I felt as practically all of the mill men have felt that this difference in speed, in height, motor base, has been one of the things that gave us the most trouble, yet I believe there has never been concerted action on the part of the mill people, or Standardization Committee, to remedy anything of this kind. And the same with the gear. As Mr. Chesrown said, we use the same motor on a mill drive that is applicable to a crane, and this reduces power equipment at least 60 per cent. Along the line of the mill motor, I feel it is a great hardship on the user for the changing of this. Each of us have 100 or 200 things standardized, and should we attempt to change this, we would find lots of things nor interchangeable, and I feel it is one of the things that should come before the Standardization Committee.

C. W. Parkhurst: This discussion has done considerable good. The mill motor has been discussed a whole lot and it seems that the Crocker-Wheeler Company deserves the credit for the modern mill motor. The fact that other companies did not adopt similar standards is our fault. We should have made them do so. The mill motor as manufactured by three of the different companies is standard as far as material, excellence, tests, and temperatures go, but is not standard in dimensions. It is too late to rectify that now.

The electric crane we wrote standard specifications for, many years ago, and we certainly reduced our troubles by doing that. It is the best crane that has ever been built, and all the big companies are using our standard specifications.

The State of Pennsylvania is working on a safety standard for electric cranes, and the standards have been copied largely from our standard specifications.

I do not agree with some of the men here on the matter of temperature rating on motors driving rolling mills. Men-

tion was made of a single rating. I do not understand what that single rating is. I hope it does not mean maximum rating, as I prefer what is known as normal rating. I have found that in designing a mill for certain conditions that after the mill is working they want to double the output or want to start with a different size bloom, or on a continuous mill they want to enter at 3rd stand instead of the first. Power requirements of mills are affected by the design of the heating furnace. If the furnace is not up to the capacity of the mill they will try to roll steel at a lower temperature than the mill was designed for, which means that the power requirements are increased several times and a normal rating on the motor is none too safe. Often the motors put on mills are too small, not on account of mistakes made in specifications, but because the mill superintendent changes his mind as to what he wants to do with that mill after it is built.

G. E. Stoltz: In regard to standardizing electrical apparatus, as suggested by Mr. Friedlaender, we would be more free to do this if we were confronted with but five or six sizes or types like the lamp people have. I believe that there is a possibility of going too far in the standardization of apparatus. Railroads standardize their track gauge, couplers, etc., but do not standardize cars, engines, etc. They are now using larger cars, heavier engines, heavier rails, and different grades of steel than they did several years ago. This has been a gradual development in all the apparatus that they employ. In the same manner electrical apparatus will be improved. We must have the assistance and ideas from every manufacturer, and fifteen years from now we may have entirely different motors.

If everybody should standardize on exact duplicate apparatus, development would not be encouraged. In order to obtain this development it is necessary that each manufacturer work along his own line; each one bringing out some feature which may be adopted by the others, and in that way be able to place on the market apparatus which is more economical and better suited to the needs of the customer. There is no question but that it would be a good idea to standardize on the temperature rating of all machines, instead of quoting on a motor having a temperature rise of

either 35, 40 or 50 degrees. It would simplify matters if this association would decide on which temperature guarantee quotations should be made. If it is desired to have a margin in the capacity of a motor, a larger rated motor could be selected instead of purchasing the machine at 35° rise.

E. Friedlaender: I think Mr. Stoltz has misunderstood me. We should not standardize details, but we should be able to interchange motors, whether bought from one or more firms. We have the A.I.E.E. standards and I do not think we need to duplicate that ground. But where we should standardize is in sizes. When standardizing in regard to interchangeability, we should not go into detail. We don't care whether the motor is made out of cast iron or steel, so long as it will meet our standard rating in temperature. We should standardize heights, length, and on pinions and speeds. We are not concerned in any details. That is up to the manufacturer.

J. H. Albrecht: I would like to say something about you gentlemen getting together on control requirements. Mr. Sage has stated when they made the specification on a motor, they found the consensus of opinion ran within 10 per cent. If we take a vote on the control question, I feel sure it wouldn't come within one hundred per cent. Take a small detail like overload protection; one of you gentlemen will say that I don't want any. Another will say, I want two. I think it would be an important matter for this Association to get together and arrive at a standard method of laying out controllers; state whether you want overload protection, knife switch, protecting relays, and features of that kind. If you decide on a standard, I think we can make it for you.

W. Jones: Regarding the standardization of the mill motor itself, I do not think there will be so much trouble about that. The only thing I see that we cannot standardize on is the interchangeability of different makes.

F. D. Egan: In the past we bought what was referred to as a standard motor, and when we would put in an order to buy a duplicate motor, we were advised we could not buy it. That means you have to start in and buy a lot of spare parts. If you visit a storeroom in any steel mill, you will find anywhere from 50 to 75 per cent. of the stock is elect-

rical apparatus, and when we add additional lines, it causes more trouble and outlay. I do not believe that changing so rapidly is a good thing.

Otto Schaumberg: It is quite uncertain to predict, at the present just how far the various motor manufacturers may go in standardizing their electric motors so that one make can be replaced by another without making any changes on the machinery to be driven. While such an agreement, if you please to call it such, would be ideal from the purchaser's viewpoint it would, however, mean expenditures of millions of dollars to the manufacturers for which directly, as far as I can see, no profit could be accounted. But, why try to engineer the most serious and complicated task first; I sure have reason to believe that your Standardization Committee has lots of possibilities before them to standardize within the next two or three years on smaller apparatus or machinery which is more or less special at the present with the various leading electrical manufacturers.

Let us, for an example, mention the various types of magnetic controllers and starters. If I recall right, about a year ago we had a standardization meeting pertaining especially to controllers. So far, gentlemen, I fail to see the results of this meeting of a year ago. The great number of inquiries which come to my attention from the various steel mills of this country, I regret to notice, are far from what you would call uniform.

Another example, my record shows that about 95 per cent of the engineers in steel mills are using the tapered shaft on typical installations where the steel mill type motor is used. How does it come that the remaining 5% cannot come in line and standardize with the remaining 95%.

Within the last four or five years, it must be admitted your Standardization Committee has done a lot of excellent work towards standardization by which not only the steel industries but also a great many other industries have benefitted, and, I safely can take the responsibility upon me to offer my Company's expert service to further the good work of your Committee.

H. J. Fisher: I think Mr. Snyder misunderstood Mr. Stratton's statements. Mr. Stratton did not mean to say

the rules were not good, but that competitors did not live up to them. The point he meant to bring out was that mills try to change more than they can. They should change little by little, and, eventually, have all points standardized; whereas, if you try to standardize everything all at once, all the competitors wouldn't live up to it.

W. V. C. Brandt: There is one phase of standardization that has not been touched on tonight—I think probably all the rest have. There are some thirteen electrical organizations in Pittsburgh. A great many of us belong to several of them. These members, who belong to a number of these organizations, cannot follow all meetings. Suppose we standardize at our meetings, and take up the subject of motors. The A.I.E.E. are interested in motors. They will have a meeting this month and cover the same ground. If these different organizations get together and have a good subject, it will be a great help to all members. There is a movement on foot to form an association of the various organizations in Pittsburgh for that purpose. I think your directors are familiar with it. It is moving along nicely, but slowly. When the time comes to vote on the welcoming of these different Associations, we would like to have your support.

F. D. Egan: We have not attempted, as the manufacturers seem to think, the standardization of any parts. We have attempted a number of times to get meetings of the Standardization Committee, but it is a hard matter. So the intention of the meeting tonight was to endeavor to find out what the views and opinions were of the manufacturers, as well as the mill men, and with that in view it would be possible for the Standardization Committee to attempt to do something if there was a real need; and I feel that since the discussion tonight we can more zealously get down to work than we could in the past. It was not the intention of forming any specifications. The only things we have standard specifications for is the crane, motor-generators, large transformers and the large mill motor. I feel, as our President, Mr. Snyder, has said, that nothing has done as much good as that specification gotten up in 1907. If a person who is *familiar with that specification* would examine the specifica-

tions of the steel companies today, he would find that 75 per cent. of the recommendations are carried out.

W. T. Snyder: I was glad to hear the Chairman of the Standardization Committee say his Committee is ready to get down to work, and I hope we will get something from their good resolution. I want to congratulate the Standardization Committee on their program this evening. We have had a good many interesting meetings, and this has been just as interesting as any we have had in the past under the direction of other committees; and my only regret is that we don't have more mill men here, to hear what is going on if they don't want to take part in the discussion. I also regret that the mill men were not here to take their part. Some had good and legitimate reasons, I know; whether all did, I do not know. We were glad to have had the Jovians with us this evening, and hope we will have the pleasure of having them with us again.



MIXED FLOW TURBINES ✓

By M. I. NUSIM

It will help to understand the present subject if we first mention the broad principles which form the basis of all our knowledge of steam turbine work. We must realize in the first place that complete information on the properties of steam must be available. This information is now embodied in modern steam tables which have standardized all the experimental and theoretical data on the thermal properties of steam. Steam tables give us complete information on the amount of heat necessary to generate steam, that is, the heat contents in 1-lb. of steam over the complete range of practical application. You will find in modern steam tables very valuable data on the properties of superheated steam, the result of extensive investigations during the last ten years.

In the second place, it is well to point out that only a fraction of the total heat in the steam is available for doing work, even in a perfect turbine having no losses of any kind. To bring out more forcibly the fact that only a fraction of the initial heat is available for doing work, consider the following illustration:

A water wheel is driving a 50-kw. generator, say the load on the generator is a rheostat which acts as a heater to generate steam in a boiler. Therefore the electrical energy is being transformed into an equal amount of heat energy represented by a definite rate of steam supply from the boiler; now if this amount of steam so generated is used in a turbine it will not be possible to obtain the initial output of 50-kw. delivered by the generator, but only a fraction of it.

The difference between the initial total heat and that utilized in producing work, is the heat contained in the steam as it leaves the exhaust opening of the turbine.

The initial total heat in the steam and that fraction of it which is available for doing work is entirely determined by the initial steam pressure and temperature and by the final pressure at the exhaust end of the turbine.

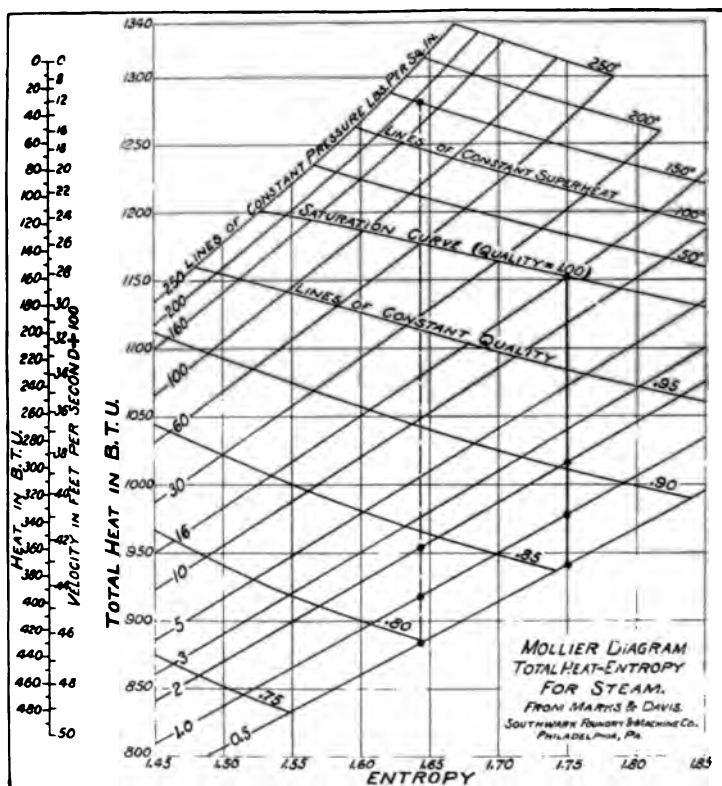


Fig. 1

Let us consider steam initially at 175-lbs. gauge, 150° superheat and expanding to 29" vacuum or 1/2-lb. per sq. in. absolute, see Fig. 1. The initial heat per lb. of steam is 1281 b.t.u.—the available heat for doing work is 400 b.t.u., that is only about 1/3 of the total heat absorbed in steam generation. Actually on account of internal friction losses in the turbine, the useful output per lb. of steam in a good tur-

bine is about one-fourth of the heat absorbed in steam generation, the remaining three-fourths is carried away by the circulating water in the condenser. The temperature of the exhaust steam (80° to 100°F.) is too low to be utilized for heating and must be considered as a total loss.

As a second illustration, consider steam at the same initial conditions as above, namely, 175 lbs. gauge and 150° superheat, but expanding to 25 lbs. per sq. in. absolute in a turbine running non-condensing. In this case, 170 b.t.u. per lb. of steam is available for doing work, or about 14% of the total heat. The remainder as well as the friction losses in the turbine can be utilized for steam heating since the exhaust temperature is higher, namely, about 240°F. The most economical arrangement is therefore the generation of power with non-condensing turbines, provided that there is a demand to utilize all the exhaust steam for heating. For in this case all the heat supplied can be accounted for on the right side of the ledger. Even the internal friction losses in the turbine appear as heat in the exhaust steam which can be utilized. The same can of course be said of that fraction of the steam which is extracted for heating in the bleeder turbine.

Finally consider the case very common in steel mills, where large quantities of low pressure steam are available for power purposes. Initially dry steam at a pressure of 16 lbs. per sq. in. absolute has a total heat per lb. of 1150 b.t.u. When this low pressure steam expands to a vacuum of 29", an amount of heat equal to 210 b.t.u. per lb. is available for doing work, which should be noticed is about one-half of the available energy, for the first case considered.

Now one of the virtues of the steam turbines is that it is adaptable for any of the steam conditions mentioned above. No difficulty should be experienced in designing a turbine for any range of energy covered by steam charts and regardless of initial or final conditions as to pressure and temperature. Furthermore, the efficiency of the turbine can be made to be practically the same, regardless of the range of energy utilized. What really determines the efficiency of commercial units are methods of manufacturing, development, cost and competition.

We have so far considered the thermal properties of steam as related to non-condensing and bleeder turbines which furnish steam for heating, or low pressure turbines which utilize low pressure steam for power purposes. We desire to point out next the characteristic manner in which the available energy is utilized in steam turbines. All types of turbines have this in common, that the available energy is utilized in producing steam jets in alternating rows of stationary and moving buckets. These steam jets act on the movable buckets and thus do work. The total range of available energy is utilized generally in a number of stages in series, a condition which enables a turbine to readily adapt itself for mixed flow operation.

We will proceed to review briefly the various types of turbines which either furnish low pressure steam for heating or utilize low pressure steam for power. Of these types, only the mixed pressure turbine—that is the turbine that can operate either on low pressure or high pressure steam—offers any special problems in design, relating, namely, to the method of governing, so as to automatically adapt itself to the amount of low pressure steam available. A design for a mixed pressure governor as built by the Southwark Foundry and Machine Company for turbo-generators and turbo-blowers will be explained later.

We will briefly review the various types of turbines that can be classed under the subject of this talk.

STRAIGHT NON-CONDENSING TURBINES

As stated previously, an ideal method of power generation is by means of non-condensing turbines, provided that all the exhaust steam can be utilized for heating. For this case, the power obtained can be considered as a by-product. There are a number of installations of this kind for units of capacity up to 1500-kw. It is interesting to note that such turbines can generally be built to have a comparatively good efficiency, say about 70%. In fact this efficiency is higher than that of an average condensing machine of the same capacity now on the market. It should be noted, however, that the efficiency of such a turbine is not of primary importance, if use can be made of all exhaust steam for heat-

ing, because the friction losses in the turbine appear as useful heat in the exhaust. Such turbines operate with exhaust pressure varying between zero to 15 or 20-lbs. per sq. in., gauge.

The non-condensing turbines referred to so far are for installation where the exhaust heat is used for manufacturing purposes all the year around. When the exhaust steam is used for heating buildings, it is sometimes advisable to install a straight non-condensing turbine that would operate

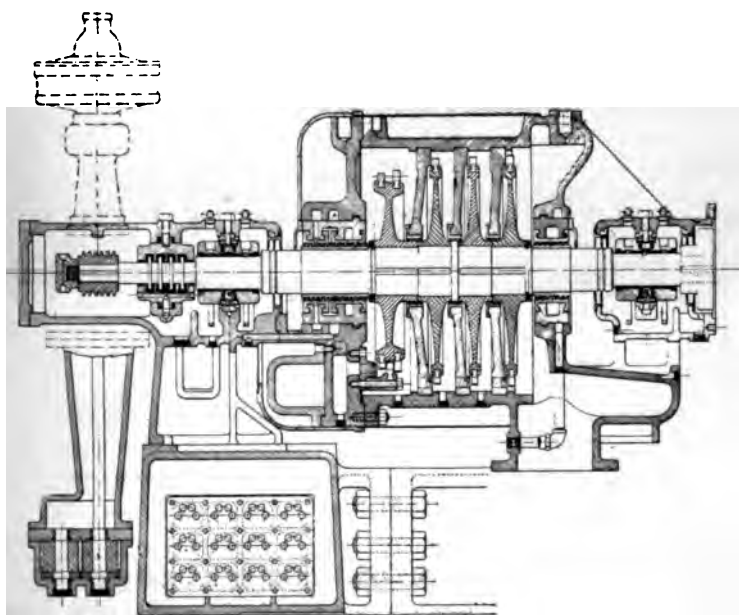


Fig. 2

condensing during summer months. This arrangement is to be recommended in plants where a condenser large enough to accommodate such a turbine is already a part of the equipment. The advantages are low first-cost, since a non-condensing machine is generally cheaper than a condensing machine of the same size. A straight non-condensing turbine (as shown in Figure 2) will show a fair improvement in water rate when operating condensing with a vacuum not exceeding, say 26" or 27" of mercury.

STRAIGHT CONDENSING TURBINES OCCASIONALLY OPERATING NON-CONDENSING

In some installations it pays to shut down the condenser and run the turbine non-condensing at such periods when the exhaust steam can be used for heating. It is, of course, necessary that the turbine should be designed to carry full load non-condensing. It is well to keep in mind that a turbine can be arranged so as to carry full load non-condensing without any sacrifice in steam economy when operating condensing and without any marked increase in cost. It is, of course, important that the designer should know the non-condensing requirements beforehand.

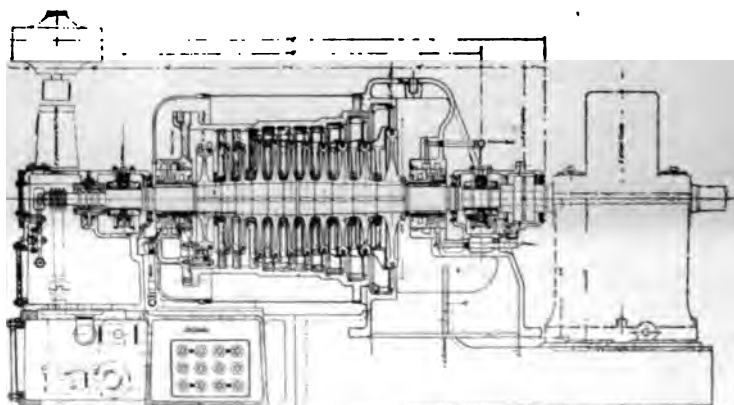


Fig. 3

STEAM EXTRACTION OR BLEEDER TURBINES

We will now consider a mixed flow turbine. It is common practice to adapt condensing turbines for steam extraction. The first stage-pressure in a machine of this type, (Figure 3) is about 50-lbs. per sq. in. gauge. It is possible, therefore, to provide an opening in the first stage from which various amounts of steam can be extracted for manufacturing or heating purposes. No special devices are necessary beyond a pressure-reducing valve in the extraction line. The first stage pressure will, of course, vary with the load and with the amount of steam extracted. The pressure-reducing valve in the extraction line will maintain the desired constant pressure by throttling (5 to 10 lbs.) This thrott-

ling in the extraction line is, of course, not objectionable since all the heat is still available for the purpose on hand. There is, of course, no internal throttling for that part of the steam that flows through the turbine and acts on the blades. There is a minimum load below which no steam can be extracted, because of the low first stage pressure (see Fig. 4). For any load the amount of steam that can be extracted increases as the extraction pressure decreases, because of the fact that with the lower first stage pressure, less steam flows to the condenser and therefore more steam can be extracted to maintain the load. We repeat, all that was stated above applies for a straight condensing machine with

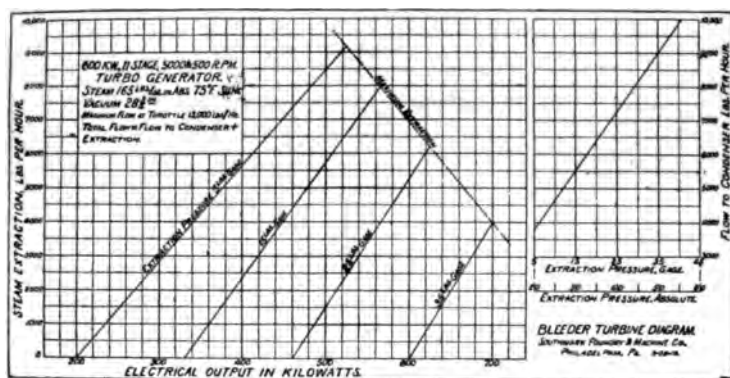


Fig. 4

no other provision for steam extraction except the opening in the casing.

Experience has shown that in many cases a machine of this kind generally fulfills all the requirements for steam extraction, thus avoiding mechanical complications, higher first cost and any compromise of turbine performance when operating straight condensing without any steam extraction. Turbines can also be designed to maintain automatically the stage pressure and hence the extraction line pressure constant, by special internal valves. These valves regulate the flow to the condenser to suit variable extraction requirements and various loads.

STEAM COMPRESSORS

Before leaving this subject, it may be interesting to mention that at some plants, particularly oil refineries, the low pressure steam available from various sources must be compressed to about 10 lbs. per sq. in. gauge, before it can be applied for heating in special apparatus. The compressors are of the centrifugal type, driven by turbines using live steam directly from the boilers and exhausting at 10 lbs. per sq. in. gauge; the exhaust steam from the drivers being utilized for heating purposes. In other words, it pays to compress low pressure steam to some higher pressure which may be demanded by heating apparatus and then applied for heating.

LOW PRESSURE TURBINES

This type is designed to utilize for power, low pressure steam that may be available from various sources. These turbines are, of course, operating condensing. They do not offer any peculiarity of design, except that on account of the lower available energy per lb. of steam, fewer stages are necessary as compared with the straight high pressure condensing machine. It is also well to point out that the amount of steam for a given load is approximately twice that required for a straight high pressure condensing machine of the same capacity. No special methods of speed control are necessary.

A familiar application of the low pressure turbines is to operate them in series with existing reciprocating engines and thereby increase the plant capacity. When both engines and low pressure turbines are driving alternators connected to the same bus-bars, it is well known that no speed governor is necessary for the low pressure unit, since the governing is being taken care of by the high pressure unit.

For central station work, where floor space is of great importance, experience has shown that the installation of low pressure turbines in series with existing reciprocating engines is not to be recommended. The station capacity can be increased more effectively by eliminating the reciprocating units altogether and installing straight high pressure condensing turbines.

For steel mills a mixed pressure turbine is generally preferred and this type will be discussed next.

MIXED PRESSURE TURBINES

The characteristic feature of this type is the provision of two distinct groups of wheels or stages. One group is formed by the low pressure bucket wheels, supplied with low pressure steam through a special opening in the casing. The second group is formed by a number of bucket wheels which run idle when sufficient low pressure steam is available to carry the load, and become effective when the supply of low pressure steam is entirely shut off, in which case the turbine operates as a straight condensing unit. They also become operative when the amount of low pressure steam available

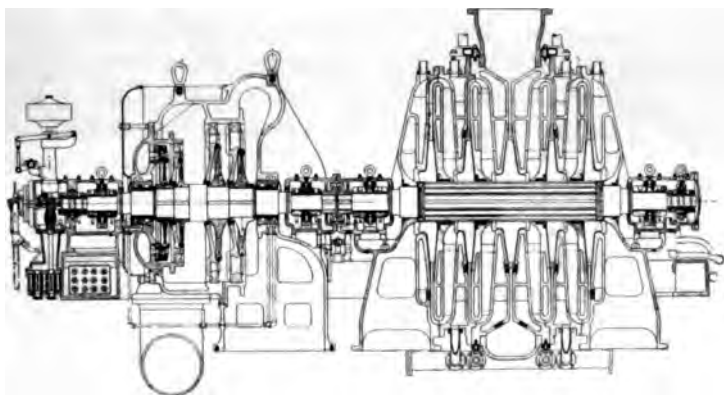


Fig. 5

is insufficient to carry the load and an additional supply of high pressure steam is necessary, in which case the turbine is operating as a mixed pressure unit. It should be understood that the steam flowing through the high pressure wheels also acts successively on the low pressure wheels.

Fig. 5 shows a 3,000 h.p., 3,600 r.p.m. turbine, driving a centrifugal blower for Bessemer service, the low pressure element consists of two bucket wheels which have diameter appreciably larger than the two high pressure wheels. This is in order to reduce windage losses of the high pressure element when the turbine is operating with low pressure steam only. For low pressure operation, the energy is about equal-

ly divided between the two low pressure wheels, thus with an initial pressure of 16 lbs. per sq. in. absolute and an exhaust pressure of 1 lb. per sq. in. absolute, the stage pressure will be about $4\frac{1}{2}$ lbs. per sq. in. absolute.

When the low pressure steam is entirely cut off, all the four wheels are operating in series, as in any straight condensing machine. For this case, the stage pressures at full load of 3000 h.p. are as follows:

Initial steam pressure at the throttle, 150 lbs. per sq. in.

First stage pressure, 18 lbs. per sq. in. abs.

Second stage pressure, $8\frac{1}{2}$ lbs. per sq. in. abs.

Third stage pressure, 3 lbs. per sq. in. abs.

Exhaust pressure, 1 lb. per sq. in. abs.

The available energy utilized in the first stage is appreciably higher than in any of the following stages on account of the use of a Curtis element in this stage. The division of energy for this high pressure condition is very satisfactory; in fact, no compromise is effected in obtaining good performance with either straight low-pressure operation or straight high-pressure operation. For mixed-pressure operation when only a small amount of high-pressure steam is necessary to carry full load, the second stage operates at a disadvantage, because the available energy to be utilized for that stage will be lower than suited for maximum efficiency. It should be noted, however, that it is better suited than any other stage to utilize such small energies because of the fact that it has only one row of buckets of smaller pitch diameter.

This turbine will carry full load non-condensing in case the condenser should break down. For this purpose an overload valve is provided, admitting high-pressure steam to the first stage.

Before describing the method of operating this particular machine, we will consider a mixed-pressure governor as applied to a turbine generator, (see Figure 6.) The low pressure valve and the separate high pressure valve are both under the control of a speed governor which in this case is directly connected to the shaft of the machine. This governor does not act directly on either high-pressure or low-pressure valves, but through the intermediary of a special lever

which is connected to a so-called selective cylinder. This consists of an inverted bell floating in a cylinder containing mercury. The mercury acts as a steam seal and also reduces friction. The position of inverted bell is determined by pressure inside of it, which is that of low-pressure main. With sufficient amount of low-pressure steam available, the pressure will be full value of 16 lbs. per sq. in. absolute. For this position, the special lever mentioned above keeps the high-pressure valve closed so that the speed governor can only act on the low-pressure valve, which is the desired result. When no low-pressure steam is available, the inverted

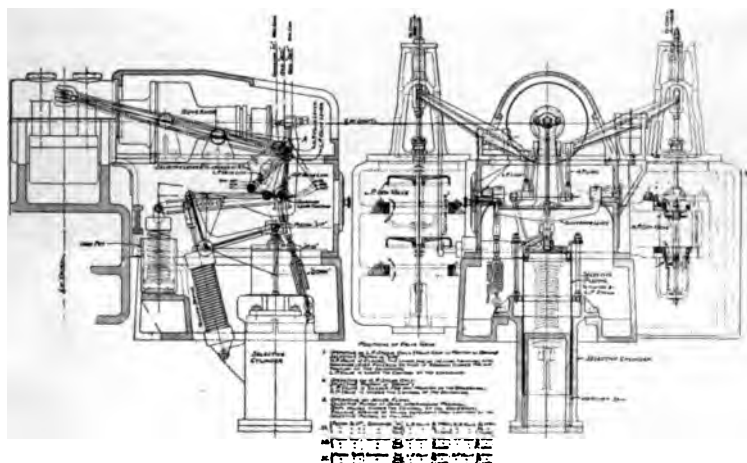


Fig. 2

bell mentioned above drops, because of the low-pressure in the line. This moves the special lever mentioned above in such a position as to close the low-pressure valve. For mixed-pressure operation, the inverted cylinder occupies an intermediate position, depending on the amount of low-pressure steam available. This intermediate position will determine the relative opening of the high-pressure and low-pressure valves and, therefore, the relative amounts of steam flowing from these two separate sources. The speed governor will in this case act simultaneously on both valves in order to govern. It will close both valves if the load falls off or it will open both valves should the load increase.

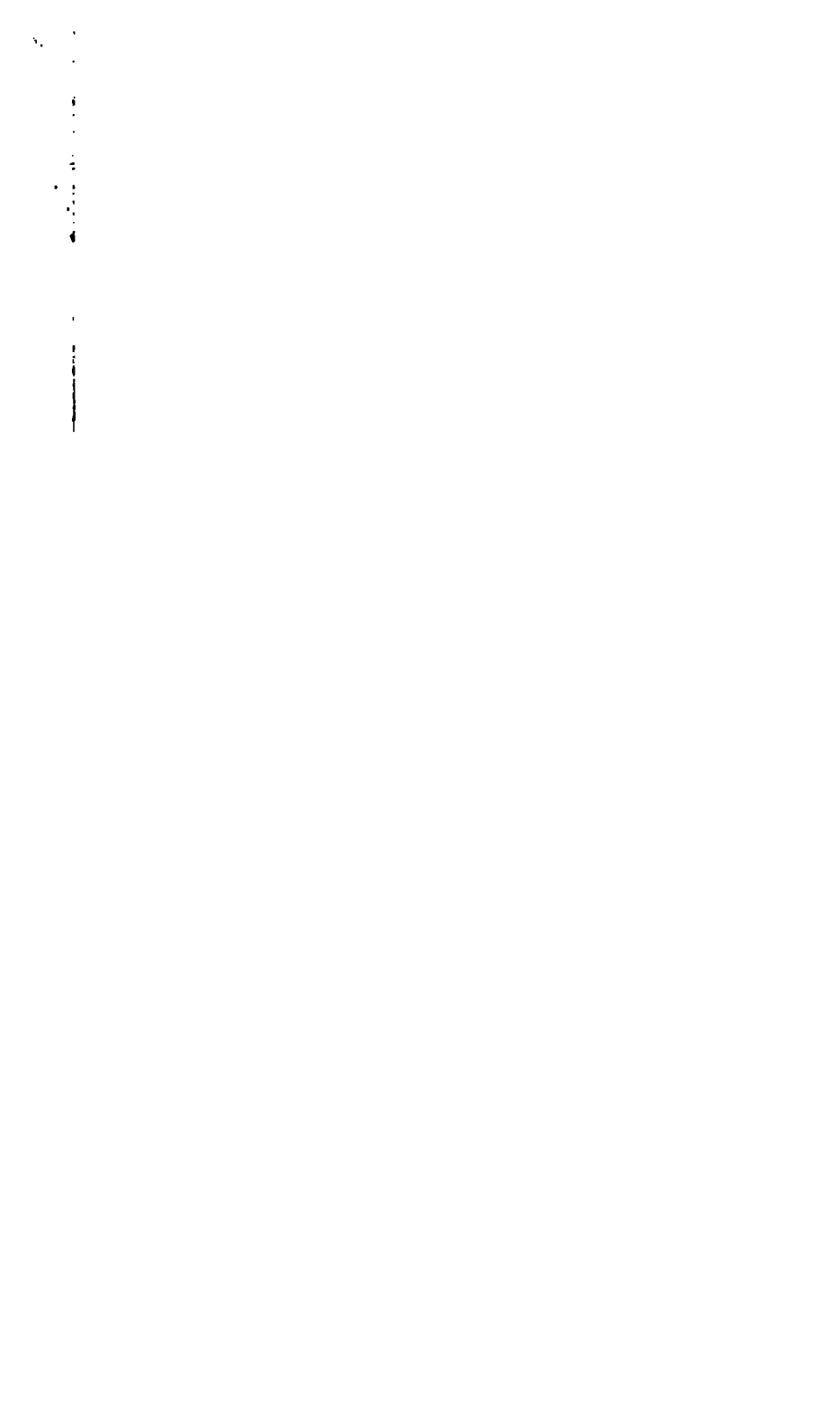
**MIXED PRESSURE GOVERNOR FOR BESSEMER
TURBO-BLOWERS.**

For this particular service the object is to maintain a constant pressure at the discharge opening of the blower. This pressure regulation is obtained by connecting the discharge of the blower to a cylinder, in which fits a piston. This piston accomplishes the constant pressure regulation by acting directly on the valve gear in such a way as to reduce the speed and close both high and low-pressure steam valves, if the air pressure tends to rise. The air piston will open both valves and increase the speed as the pressure tends to fall. The speed governor for the present purpose, acts only as a speed limiting device, that is, when the pressure regulator mentioned above tends to increase the speed of the turbine beyond a safe value, the speed governor takes hold and limits the speed to a safe pre-determined value, the same as in any turbo-generator. Below this speed the governing is done entirely by the pressure regulator mentioned above.

This being a mixed pressure unit, the mechanism also incorporates a selective cylinder such as previously described for a mixed pressure turbo-generator. Here again the selective cylinder which is an inverted cylinder floating in mercury, is applied in order to automatically take care of variable amounts of low-pressure steam. With a sufficient amount of low-pressure steam available to carry full load, this inverted cylinder will rise and by this motion it will practically lock the high-pressure valve closed or when the amount of low-pressure steam is negligible, this cylinder will drop and close the low-pressure valve entirely and the unit will then operate as a straight high-pressure condensing machine. Between these two limits of low-pressure steam supply, the inverted cylinder will occupy an intermediate position, in which case the pressure regulator which normally does the governing, will act simultaneously on both the high-pressure and the low-pressure valves, in order to maintain constant air pressure at the discharge of the blower.

The governing mechanism assumes large proportions as compared with the size of the turbine on account of the mixed-pressure gear. This is partly due to the comparative-

ly high speed of 3600 r.p.m. which enables us to obtain the guaranteed steam consumption with comparatively few number of stages, therefore, the overall dimensions of the turbine are not excessive. The blower end is of the double type with two inlets at the bottom and a single discharge opening at the top. The whole unit rests on a concrete foundation in which air ducts are provided. It is interesting to know that two machines of this type are now being built and that a number of these machines, of somewhat different design, are in operation for Bessemer service as well as for blast furnaces.



APPRENTICE SYSTEMS

Under the Auspices of Educational Committee, A. I. & S. E. E.

W. T. Snyder: The subjects of our meeting at Pittsburgh during this year are an indication of the work we try to do as an organization in the field for which we were organized to work. They are also an indication of the importance that we, as an organization, attach to the human element of the problems with which we have to deal. Our first meeting under the direction of our different committees was a safety meeting, primarily dealing with subjects pertaining to the welfare of those with whom we work. The next three meetings had to do with equipment, material, and the practical problems that are coming up from day to day in the steel industry. The next meeting, which is the meeting of this evening, is on the subject of Education; a subject, which, to my mind, is one of the most important, if not the most important, problem in the iron and steel industry, as well as other industries. We are interested in the education, not alone of our apprentices and undergraduates, but in the education and training of the entire force. We are not, as an organization, as much concerned in the secular education, that is the training of the mind or development of the memory; that we must leave to our schools, colleges and universities. We are, however, very much interested and concerned in the vocational education and training of ourselves and those with whom we come in contact in the industry. We are concerned with this phase of the education of our men in the industry because it has to do with the practical application of the theoretical knowledge that they have obtained when they come to us, and that is an important factor in the development of our great industries.

The meeting this evening will be along the line of other meetings we have conducted throughout the year in Pittsburgh, and will be under the direction of the chairman of

the Educational Committee, Mr. Chas. A. Menk, under whose direction the program for this evening was prepared.

C. A. Menk: As chairman of your Educational Committee, it gives me a great deal of pleasure to have with us tonight, some of the men who have to do with the training of the rising generation. One of these men probably has had more to do with it than anyone else I know. We have with us Mr. Alexander, of the General Electric Company, West Lynn, Mass. , who is, I understand, in charge of the educational work in their factories all over the country. He will talk to us and show us some lantern slides, showing what they are doing for the rising generation they expect to use in the future.

M. W. Alexander: Three problems of fundamental importance enter into industrial production:

The Material Problem,

The Machine Problem,

The Man Problem.

The last should also be spelled "The MAIN Problem", for it is the most important of the three. It is also the most difficult to deal with, and the most neglected; perhaps it is the most neglected because it is the most difficult. Yet on its proper solution hinges largely the success of an industrial enterprise and its capacity to maintain itself in competition with enterprises of similar character.

All manufacturers can buy materials of about the same character and grade at about the same price; they can also purchase or, if need be, design and make, or have made, machines of like productivity and cost to those used by their competitors. Moreover, they can study the successful manufacturing methods of another concern and adopt them in full or part or improve upon them. Yet when it comes to securing and maintaining the personnel and effectiveness of an industrial organization, only intelligent effort through many years will enable one manufacturer to attain the advantages in this respect which another possesses by virtue of the efficiency of his human organization.

Some eight years ago a delegation of Japanese statesmen, manufacturers and educators visited the United States and in its travels found its way to the "Hub of the Universe"—Boston. These Japanese visited among other places of in-

terest and importance, Harvard University at Cambridge, Mass., and were impressed with the arrangement of the physical property, the splendid educational facilities and the fine spirit that prevailed in this institution of learning. Turning to the then active President, Dr. Chas. W. Eliot, the spokesman of the delegation, inquired how much it would cost to duplicate the Harvard plant in Tokio. With his inimitable directness of speech, Dr. Eliot answered, "It would take but a few million dollars to duplicate the buildings and the physical apparatus in them; it would, however, take at least one hundred years to duplicate the spirit of the institution." This little incident is a pertinent illustration of the importance and character of the Man problem in industry.

There are many phases of the man problem which dovetail into each other, each of which challenges careful study and intelligent attention. How to secure the right men and women for the multiphase activities of an industrial organization; how to direct each into the sphere of greatest usefulness, so that the round peg will fit the round hole, and the square peg the square hole; how to train these men and women in their duties and, more important, how to train untrained boys and girls for industrial usefulness and efficiency and how to handle the men and women already employed, from the human as well as from the economic standpoint; how to automatically promote those who by their capacity, attitude and loyalty deserve such promotion; how to maintain the interest of workmen even in monotonous work and, generally, how to bring contentment into their present work and yet stimulate the ambition of workmen toward a better future—these are some of the vital phases of the Man problem that loom more prominently as industrial work becomes more and more complex and larger aggregations of men and women are brought into close working relationship.

I shall tonight address myself to only one aspect of the Man problem, yet one of such paramount importance that I sometimes feel that its proper solution will make the solution of all the others a comparatively easy task.

I intended at first to speak generally on the training of man, sketching in broad outline the efforts now made in the shop, in the public and private school and through co-operation of these agencies, in developing the skill and efficiency

of American workmen. On second thought, however, I decided to deal briefly with the philosophy that should underlie the training of men in industry, but to speak more fully on the successful application of this philosophy to a practical effort in industry with which I have been personally connected since its beginning. In speaking thus concretely of one industrial educational effort, I want to make it clear that I am not endeavoring to propound any one system of training of men as against any other successful system, for I know too well that the surrounding conditions and the personality of the men available for the work are paramount factors in determining the efficacy of one or another method. I claim, however, that the broad principles underlying the training of men in this instance are equally and as successfully applicable to similar work in other industrial establishments though they will have to be modified in degree to suit their size and character.

Efforts to teach the young man, whether young in age or experience, the knowledge or skill already acquired by his older brother, is as old as mankind. With the social and economic changes which develop during the centuries, the character of the problem varied, changing at first from the need of a purely vocational to that of a more pronounced scholastic training.

During the last century, however, the vocational aspect again forged prominently to the front, especially in countries like United States in which industrial activities rapidly began to predominate over agricultural, and the system of education had to accommodate itself to the new requirements. Thus the teaching of the mechanical arts developed on a large scale; a marked impetus was given it in the United States by the industrial reconstruction period following the Civil War. As new industrial enterprises were started and as older ones grew larger, their owners made it their concern to teach young fellows the practical work in which they themselves were engaged. Soon, under the influence of American genius, industry expanded at such a rapid pace that it became necessary to specialize in industrial processes to a larger degree than ever before. Somewhat misled by the immediate results of specialization which permitted the effective employment of semi-skilled and even unskilled work-

men, employers came to believe that the need for well-trained all-round skilled mechanics was now less important, and they discontinued to a large extent their efforts for systematic trade training.

But these employers failed to consider that the greater specialization of industry on the basis of wholesale production, and with it the utilization of multitudes of workers, required a large number of highly trained men to lead and direct this ever-growing industrial army. They did not realize that the more complex machinery, through which specialization was largely made possible, also called for a higher type of all-round mechanics to design, construct and install this machinery. About that time, also, manual training began to be introduced into the public school system and employers readily shirked their responsibility for the training of craftsmen by shifting it to the public school without, however, any assurance that the schools would be able to develop quickly and effectively the required type of industrial workers.

American employers, however, soon become disillusionized. The exhibition in Chicago in 1903 displayed the products of the mechanical skill of foreign nations so impressively as to awaken American employers to the necessities of the situation. Once more they realized that the final responsibility for training skilled workers must rest upon them, even though they might, as they should, take justified advantage of the valuable help which public schools could render. The thought was born anew among employers that only through the revival of the apprenticeship system, modified to suit new industrial conditions, could they secure the superior intelligent skill through which they could fortify themselves against foreign competition.

Quite a few examples of effective trade training in industry can be cited; their number, however, is only as a drop in the bucket when it is remembered that there are about 300,000 manufacturing establishments in the United States, each with its need of skilled or semi-skilled workers. Most employers are giving little heed to this pressing need; yet unless American employers generally shall awaken quickly to the necessity of developing an adequate and continuing supply of intelligent workers who shall be masters of their craft, the day will speedily come when American made pro-

ducts will largely be supplanted by those of foreign manufacture.

The average employer, not from necessity but because of thoughtlessness or habit, still prefers to get workmen whom someone else has trained. But if he can be shown by concrete examples that he can readily train his own skilled workers to meet the special requirements of his business as well as to be all-round mechanics of general usefulness, the chances are that he will sense his responsibility and, with the usual enterprise and acumen of the American business man, will apply himself seriously to the task.

On this basis I am glad to speak of the practical efforts of the General Electric Company for effective training of men. I am confining myself to a description, by word and picture, of the educational systems established at the Lynn Works of the Company, because the system originated there and has been developed to a greater extent at Lynn than at the other plants where, however, the same general system is in force.

While the General Electric Company today employs over 65,000 men and women in the United States, not counting employees in foreign factories, the Lynn Works gave employment to only about 4,000 people in 1902 when the educational system was inaugurated. Though the Lynn Works now employs over 13,000 people and its educational system has expanded to meet the new requirement the essential features of the system have remained unchanged.

Four distinct phases of systematized educational effort have been developed, which respectively aim to train young men for engineering and administrative efficiency and leadership, for semi-professional service, for specialized mechanical skill, or for all-round manual proficiency.

The first phase is adapted to selected graduates of electrical, mechanical and general science departments of colleges and universities who, during a two-year course, are given carefully supervised training in the practical application of engineering theories. Many of them are also given brief experience in some of the business departments before they are permanently assigned to engineering or administrative service in the company or assisted to secure such employment in other corporations. It is not feasible within the

time available to describe in detail the many interesting aspects of this important work.

The second phase is designed to accommodate selected graduates of high schools or equivalent educational institutions who, though fitted for a college training, cannot or do not want to avail themselves of it, but are anxious to secure a fair equivalent of technical education through practical experience. A three-year course is maintained for these future draftsmen and designers, electrical and steam turbine testers, manufacturing and erecting engineers, technical clerks and cost accountants. The practical side of their work is taught in specially supervised machine shops and winding departments, drawing rooms, testing rooms, stock rooms and other business offices of the Company. Their related educational instructions in class rooms is based on a high school education and deals primarily with advanced mathematics, physics, drawing and engineering subjects, as far as the limited time available each day for such instruction permits. Further consideration will be given to this phase in the detailed discussion of the Company's efforts for training skilled mechanics.

The third phase pertains to that large group of adults who have not had opportunity to acquire mechanical knowledge and specialized technical experience or who have failed to grasp such opportunity in their younger years, but who still possess mental capacity, physical vigor and ambition to raise themselves with somebody's help to a higher level of industrial usefulness and resulting remuneration. Six months specialized courses are provided for this group, to learn to operate a lathe, a shaper, a boring mill or some other machine, or to do similarly effective work of specialized character. With pay adequate to maintain themselves decently during this period of learning, those who successfully finish the six months specialist course are enabled to earn good wages as regular workers in their particular field of industrial activity. The specially capable and ambitious are permitted to take successive six months specialist courses to acquire knowledge and skill in the operation of various machines or in various manufacturing processes, thus step by step developing into all-round skilled operatives. This very brief description of a very important step towards industrial

efficiency must suffice to direct attention to the general application of this phase of industrial education.

The fourth phase is obviously the most important, for it seeks to create from among boys with ordinary school education, that class of intelligent and highly skilled artisans upon whom the development of American industry ultimately depends. This phase, generally known as the apprenticeship system, is designed to take care of boys who must leave or who prefer to leave school after they have passed through the Grammar grades or partly through the High school and who desire to become mechanics, foremen, superintendents and leaders in industrial establishments. Most of these boys will naturally drift into industry, especially if they are located in industrial communities, but few of them will, unless properly assisted, become skilled and intelligent machinists, toolmakers, die makers, carpenters and pattern-makers, moulders, blacksmiths, steam fitters or any of the other artisans whom industry needs. The demand for persevering, energetic men of well founded fundamental and specialized knowledge, with the power to apply the theory of science to the practical requirements of industrial life, is growing daily.

To supply a part of this demand, an apprentice system which contained several new features, was started at the Lynn Works in 1902 and later extended to the other factories of the General Electric Co.

Under the old form of apprenticeship, a boy was taken into a shop and turned over to a foreman who was expected to teach him the trade. The foreman, himself very busy in his regular duties, and usually more adapted by experience and inclination to the production of manufactured materials than to the training of boys, would turn the boy over to an assistant foreman, who in turn would pass him down the line until he landed under the supervision of a mechanic, skilled or partly skilled as the case may be, but not often able to impart his skill to the boy. (After all, how many persons in any position of life, are really good teachers?) Frequently also the run of work in a shop was not sufficiently varied to give to the boy broad experience of instructive character. Even though the boy's supervisor might have the ability to impart his knowledge and might also be able to

give to the boy such a varied assortment of work as to afford him a broad opportunity to learn the trade, the apprentice was himself seriously handicapped by his own limited education. Employed at work that required the use of drawings, he could not understand them nor could he make a simple mechanical sketch; if a mechanical operation required the use of mathematical formulas that were not included in his limited school experience, he of course failed and had to forego doing the higher grade of work that such knowledge would have brought within his range. Many employers have fully sensed this situation and have induced their apprentices to take evening courses at public schools and other educational institutions, but with only meager success, largely because the day's work was in itself as much of a task as the apprentice cared to undertake, and partly because he was really too tired at the end of the day to do good school work at night.

Realizing then that these factors were largely responsible for the failure of apprenticeship systems, the General Electric Company established in the Lynn Works special departments devoted exclusively to the training of apprentices and placed them under the supervision of highly skilled men whom nature and training had endowed with the faculty of teaching others. And so there will be found within the big machine departments a small machine shop, and within the big wood-working shops a small pattern-making shop, set aside for training of boys under supervision of men well qualified for developing boys' aptitude for mechanical work. Readily accessible classrooms were constructed, in which every apprentice was required to devote, but on full pay, a part of his working hours to classroom study and where, under competent instructors, he was taught those branches of technical knowledge that would assist him in attaining the goal of his mechanical or engineering ambition.

The idea of maintaining special training rooms in factories was new. All operations in these rooms are on commercial work which otherwise would have to be done by regular operatives; yet the work is carefully selected for its instructive character. The value of training apprentices on commercial work lies in the fact that the elements of time, money value and usefulness immediately impress themselves

upon the mind of the apprentice, acting as a stimulus and incentive to him to put forth his best efforts.

The other new idea was the introduction of classroom instruction into the factory. The Company insists that every apprentice receive training of his mind as well as of his hand, in order to develop, not human automatons, but skillful, intelligent and loyal artisans. Realizing that an apprentice is entitled to play and rest in the evening after a day's work, and that he would unwillingly go to classroom study if it meant a partial loss of his wages or a restriction of his time for recreation, the Company inaugurated the plan of giving the classroom instruction during the working day and without loss of wage to the apprentice.

The underlying reason for this procedure is based on the conviction that most boys leave school as early as permitted and go to work, partly because school has become to them a drudgery and partly because they want to earn money. The apprentice school studies are therefore made so interesting and so correlated to the practical work as to attract the apprentice; and his wages are paid whether he is working in the training room or studying in the classroom. Otherwise, most apprentices would go into the classroom, not because they like it but because they must, and consequently they would not get full benefit from the Company's educational effort; they "would have eyes but see not and ears but hear not."

At first sight, the comparatively large expenditure for salaries of classroom instructors and for wages paid to apprentices for non-productive time spent in classroom would seem unjustified. Experience, however, has shown otherwise, for the added intelligence acquired in the classroom makes the apprentice do more and better work in the shop.

As for apprentice wages, the Company decided to pay remuneration right from the beginning of the course, even during trial period, and to pay sufficient wages to allow even boys from poor families to enter the apprenticeship department on a self-supporting basis. Gradually the wage schedule increased with the general increase of wages in industry, until today all apprentices receive at least \$5.50 per week at the start, with periodical increases at the rate of from \$1.00 to \$1.50 per week for each succeeding year of appren-

tice training. A cash bonus of \$100.00 is paid at the successful termination of the prescribed training period, when the apprentice is also awarded a Certificate of Apprenticeship which entitles him to recognition as a full-fledged journeyman and outlines the course of training which he has successfully pursued.

The apprenticeship period for grammar school graduates is four years, except in the case of moulder apprentices, who may finish their course within three years; iron and steel moulder apprentices, however, must be at least eighteen years of age to undertake this somewhat more arduous work, and they are paid higher wages. The apprenticeship period for high school graduates is three years and these apprentices receive wages beginning with \$6.50 per week and increasing to \$11.00 per week.

As far as business conditions permit, graduate apprentices are encouraged to remain in the service of the General Electric Company. There is no fixed standard of wages for graduate apprentices; each case is settled on its own merits. The average rate, however, is from \$3.00 to \$3.50 per day, with splendid prospects for advancement either in the service of the Company or in that of other industrial establishments.

All apprentices are required to serve a trial period of about 2 months, during which time they are closely observed to ascertain whether they possess natural ability for the chosen work and if they have the moral stamina and general intelligence required to successfully complete course. Only those who give satisfactory promise during the trial period, are allowed to sign in conjunction with their father or guardian, a standard agreement which outlines the conditions of apprenticeship. The apprentice is distinctly told that the agreement has no legal force and may be broken by him without fear of prosecution. He is made to understand, however, that the agreement is in the nature of a promise made by one gentlemen to another: the one—the Company—promising to teach the trade and pay stipulated wages; the other—the apprentice—promising to give satisfaction in his work and deportment.

Experience has shown that boys employed on this basis are more apt to live up to the agreement than if they were working under the impression that it is being used as a club

to force them to continue at work. It is remarkable what a small percentage of apprentices "jump" the course after signing the agreement; the average is less than 5%.

Contrary to general practice, the recruit in the Apprentice Department is not required to do ordinary chores such as sweeping floors or running errands; he is immediately put at a machine or a bench to perform simple mechanical operations that are strictly in line with the trade he desires to learn. Jimmy might sweep the floor ever so clean and carry messages ever so quickly and yet be naturally unfit for the trade. It therefore behooves us to find out as quickly as we can if Jimmy, who wants to become a machinist, has an embryo machinist in his makeup; if there is no future machinist in him it would be futile to attempt to draw one out of him. The sooner we definitely learn this, the better for the boy and for the Company; otherwise he and we would waste valuable time and we would retard Jimmy's progress and injure his reputation if we should be compelled later to discharge him for lack of natural ability. The stricter the process of weeding out during the trial period, the easier the subsequent task of training and retaining apprentices.

Many very interesting features of this system are worthy of a somewhat detailed description. The illustrations shown in connection therewith will make the description more clear.

The training room for machinists and tool and die makers, shown in figure 1 is located on the top floor of a modern building and occupies a space 460 ft. long, 80 ft. wide. The doorway in the distance leads to a corridor from which entrance is made to the classrooms. All rooms are well lighted, well ventilated and kept as clean as shop practice will permit. The influence of the clean and orderly shop develops the apprentice's instinct towards neatness and cleanliness about his machine or bench, as well as his personal habits. The very cleanliness of the place induces the apprentices to stop spitting; there is not a "No Spitting" sign in this shop. All machines are of the more modern type; all are motor driven and properly safeguarded. Similar conditions prevail in the training room for pattern-maker apprentices, as shown in figure 2, and indeed in all of the apprentice training rooms.



Fig. 1



Fig. 2

In each apprentice department a wide variety of work is done and a broad range of machines is provided with which to do it; this excites the boy's interest and gives him a wide and valuable practical experience. There is no hard and fast rule to govern the time during which an apprentice shall be trained on one kind of machine or on one class of work; this depends on the ability which each apprentice shows and is somewhat controlled by the character and volume of productive work which the department can secure. Generally, however, satisfaction is attained when an apprentice can do the required work with absolute commercial accuracy and a fair degree of speed. When he has reached this stage on a particular operation, he is often required to help in the training of another apprentice who has not yet advanced as far. He is made a leader in what we call a "team"; that is, he becomes a boy-teacher of a boy-pupil. The system disregards the age and service-period of an apprentice. The more capable teaches the less capable even though the latter is older; the boys are taught to respect the skill of those who have gained greater proficiency. When the boy-teacher has taught the boy-pupil to understand the work and to do it accurately, the boy-teacher is promoted to a different class of work, most likely in the capacity of a boy-pupil to a yet more proficient apprentice.

By this team practice the executive ability of six skilled adult instructors is expanded to meet the needs of some two-hundred apprentices engaged in one training room. In many respects better results are obtained than if the instructors personally supervised each apprentice, for the boy-teacher gets into closer relationship with his pupil. At the same time the executive ability of the boy-teacher is developed and the importance of doing work right is more indelibly impressed upon himself as he strives to impress it on another boy. This method also trains those apprentices for future foremanship who have native though undeveloped ability for handling men and supervising their work. Moreover, by the boy-teacher-boy-pupil arrangement it is readily learned how much ability and willingness to learn an apprentice possesses, for the boy-teacher who is retarded in his own advancement by a slow pupil, is quick to complain if his pupil is slow to grasp mechanical details or lacks interest in the



Fig. 3



Fig. 4

work. If the complaint seems justified and is indeed not the boy-teacher's own fault, the regular instructor takes the apprentice complained of under his personal care in an endeavor to stimulate him. Sometimes he succeeds but more often he confirms the boy-teacher's judgment and must discharge the apprentice.

A section of the training room devoted to tool and die making is shown in figure 3. This work, of course, requires skillful and accurate treatment and is only done by more advanced apprentices.

An important part of the work in electrical manufacture has to do with the winding of coils, fields, armatures and similar elements. Skilled winders are not plentiful; rapid expansion in the use of electrical power in industry and in public service work is creating a greater demand for them. With this thought in mind, the General Electric Company endeavors to train some apprentices in this particular line of work. Usually boys with a high school education are employed here; they wind armatures and fields and test them for commercial use; they also strip and rewind defective fields and armatures, a particularly instructive practice for apprentices.

Figure 4 shows tester apprentices at work in the direct motor testing department; such apprentices are also similarly employed in testing departments for other electrical apparatus.

The time spent by apprentices in their respective training rooms consists of about half the total period of apprenticeship, varying somewhat with the capacity of the apprentice and with productive conditions throughout the factory. Apprentices who have made good progress in the apprentice training room are sometimes loaned during the first half of the period to foremen in factory departments, provided the work proposed offers educational value that fits into the schedule of the apprentice course; but generally the entire last half of the apprentice course is spent in factory departments, where the apprentices gain enlarged experience and come in contact with many skilled workers. Always, however, the apprentice remains under control of the apprentice superintendent and continues the prescribed daily class room studies. If an apprentice begins to loaf or to lower his usual

standard of work or deportment after he has been transferred from the training room, it is often advisable to bring him back to the training room to serve out a period of discipline before he is again allowed to go back to the factory department. One dose of this discipline usually cures.

It may be interesting to note right here that while, previous to the establishment of training rooms for apprentices, foremen did not favor taking apprentices because they were a care—white elephants, so to speak—they now prefer partly trained apprentices to many of the men from outside who claim to be full-fledged mechanics.

The Apprentice Training Rooms are beehives of activity and models of clean and orderly workshops, equipped with various makes and styles of standard machine tools and appliances required for practical training and economical production. It should again be emphasized that all work done in these departments has a commercial value either for production, equipment or repair purposes. Nothing is done merely for the sake of following pedagogical precepts, or to make a fine exhibition of work. It is the eminently practical character of the training system which has its most wholesome influence upon apprentices and which appeals strongly to visiting observers.

The same practical policy applies to all classroom work. The courses of study are carefully planned, first to connect with the apprentices' mental capacity as denoted by their previous school education, and second to teach those sciences that definitely dovetail into the operations to be performed in the chosen field of work. Grammar school graduates, of course, start at the lowest rung of the ladder, while high school graduates skip the lower rungs already climbed during their public school experience and receive more advanced instruction, particularly in reference to mathematics, mechanics, mechanisms, thermo dynamics, magnetism and electricity.

Every apprentice is required to pursue classroom studies for an hour and a half every day except during July and August, during which months the classrooms are closed in order to give apprentices and instructors an opportunity to take a short vacation. The practical work in the training rooms, however, continues without interruption throughout

the year. For the convenience of the various training rooms in the shop departments, the classroom attendance is distributed over the day, some apprentices starting at the beginning and some toward the end of the forenoon, others at

EDUCATIONAL DEPARTMENT OF THE GENERAL ELECTRIC CO.-LYNN WORKS										
PROGRAM OF CLASS ROOM STUDIES - APPRENTICE SCHOOL										
SUBJECT	HOURS PER WEEK FOR CLASSES									TOTAL HOURS IN CLASS ROOM
	1	2	3	4	5	6	7	8	9	
Arithmetic	5									70
Algebra		5								70
Mensuration & Geometry			3½							49
Plane Trigonometry				4						56
Elements of Mechanics					4					56
Strength of Materials						4½				63
Belts and Gears							3			42
Types of Prime Movers								3		42
Practical Electricity									4	56
Mechanical & Free Hand Drawing	1½	1½	3	3	3	3				210
Tool Design							4	4		112
Machine Design									3	42
English Spelling *	½	½	½							21
Industrial History				½	½					14
Shop Economics									½	7
Practical Talks	½	½	½				½	½		35
Total Hours per Week	7½	7½	7½	7½	7½	7½	7½	7½	7½	
Total Hours per Term	105	105	105	105	105	105	105	105	105	945

The School year for 1916-1917 covers 3 terms of 14 weeks duration each, as follows

First Term from Sept. 5 to Dec. 9, 1916

Second Term from Dec. 12 to March 24, 1917
(except Dec. 25 to Jan. 2)

Third Term from Mar. 27 to June 30, 1917

* Spelling will be given only every other week in Class 1. Moulder Apprentices may terminate the school work at the satisfactory completion of the fifth class; they may substitute an extended course in Mensuration for Plane Trigonometry in the Fourth Class, and a course in Foundry Materials for Elements of Mechanics in the Fifth Class

West Lynn, June 1916

Approved *Wm. A. Alexander*

Fig. 5

the beginning and the balance toward the end of the afternoon. In order to segregate at frequent intervals the more capable from the less capable apprentices as far as the school work is concerned, the school year is divided into three

periods; advancement from one class to the other is dependent on satisfactory daily performance as well as upon the results shown at periodical examinations.

The endeavor of all the instruction is to make it concretely applicable to the practical work which the appren-


EDUCATIONAL DEPARTMENT OF THE GENERAL ELECTRIC CO.-LYNN WORKS								
PROGRAM OF CLASSROOM STUDIES - ENGINEERING SCHOOL								
SUBJECT	HOURS PER WEEK FOR CLASSES							TOTAL HOURS IN CLASS ROOM
	1	2	3	4	5	6	7	
Plane Trigonometry & Slide Rule	3							42
Advanced Algebra		3						42
Analytic Geometry		1½						21
Mechanics			3	2½				77
Introduction to Calculus				1½				21
Strength of Materials					3			42
Thermodynamics						1½	3	63
Machine Design						3		42
Turbine Design							3	42
Electrical Machine Design							2½	35
Mechanism					1½			21
Elementary Electricity A.C. & D.C.			4					56
Advanced Electricity D.C.					3			42
Advanced Electricity A.C.						2½		35
Mechanical Drawing	2½	3						77
Descriptive Geometry	½							7
Tool Design				3				42
Metallurgy	1							14
Industrial History						½		7
Shop Economics	½	½					½	21
Business English				½				7
Total Hours per week	7½	7½	7½	7½	7½	7½	9	
Total Hours per Term	105	105	105	105	105	105	126	756
<p>The school year for 1916-1917 covers three terms of 14 weeks duration each, as follows:</p> <p>First term from Sept. 5 to Dec. 9, 1916</p> <p>Second term from Dec. 12 to Mar. 24, 1917 (except Dec. 25 to Jan. 2)</p> <p>Third term from Mar. 27 to June 30, 1917</p>								
West Lynn, Mass. June, 1916				Approved 				

Fig. 6

tices pursue. Whenever possible the instructors speak in terms of materials and machinery, facilitating the understanding of the apprentice by exhibiting the objects to which they refer. The opportunities for doing this are of course

excellent in the large establishment located at Lynn with its great variety of manufacture. The high percentage record of an apprentice is a secondary object, although from an organization standpoint it may be a necessary one; to make the apprentice understand, to make him think and so to give him not only an industrial understanding but to impart and develop a general intelligence as well, is the paramount aim of the instruction.

Figures 5 and 6 show respectively the course of studies for grammar school graduates and for high school graduates, the former being trained for skillful mechanics in any of the branches taught in the Apprentice Department, the latter



Fig. 7

being developed into draftsmen, designers, testers and engineers.

The Apprentice School has nine terms, the Engineering school seven terms, these giving the apprentices the opportunity to complete their school work during the prescribed periods of apprenticeship, even if they should be held back in one or two classes.

Figure 7 shows a class room larger than usual, but better termed an assembly room, in which talks of a practical

nature are given to large groups of apprentices on subjects closely related to the shop training or to matters of allied interest. In the particular case under discussion when the camera was snapped, the superintendent was exhibiting a wrongly sharpened tool which he had found in use by an apprentice. The superintendent takes advantage of such concrete instances of error to provoke a keen discussion of the right and wrong ways of applying mechanical principles, the object being to draw out the information from the apprentices themselves rather than to offer it in lecture fashion. Other "practical talks" endeavor to explain natural phenomena, the practical applications of which the apprentices know intuitively and accept as a matter of course without usually being able to explain their cause. Why should the



Fig. 8

temperature at the top of a high mountain be considerably lower than at its base, when the top is so much nearer to the sun, the universal source of heat? Why should a one inch drill, assuming for the purpose of discussion that it absolutely retains its size, drill a larger hole in cast iron than in steel? Such questions are pertinent illustrations, the one to show the effect of the density of the atmosphere, the other to bring out the grinding effect of pulverized cast iron as it crowds behind the drill.

Practical talks, moreover, offer a splendid opportunity for the Works Physician to speak of the importance of per-

sonal hygiene, accident prevention, proper treatment of injuries; and for superintendents, foremen and department heads to explain special processes of manufacture or methods of business procedure.

Classes are usually limited to small numbers and particularly so in the higher and more technical grades. Except for the practical talks and for drawing instruction, the classes seldom number more than fifteen, but are generally twelve or less.

Figure 8 shows a class in mathematics for grammar school graduates. The teaching of mathematics and especially the branch of mensuration gives a splendid opportunity



Fig. 9

for acquainting apprentices with the very practical problems which they will meet later on as skilled mechanics, as foremen, superintendents and engineers. Much emphasis is laid on the teaching of tool design for it is realized that good ability to design jigs, fixtures and other auxiliary tools for economical manufacture of parts, reacts upon and stimulates good ability in correctly designing the parts themselves so that they can be readily machined.

The classes in mechanical drawing, and indeed all other classes, are taught on the same basis, the endeavor in each case being to use the mental instruction as a medium

through which practical shop operations will be made more clear and effective. Particular attention is directed to the necessity of proper dimensioning of drawings and especially of indicating allowable limits of manufacture, in order to insure absolute precision where precision is needed, to save the expense thus involved if it is not needed, and as a guide to inspectors in checking up the work.

A very important part of the class room instruction relates to the teaching of elementary and advanced electricity. The latter branch of this science is given only to high school graduates. Figure 9 depicts such a class engaged in the



Fig. 10

solution of electrical problems. This work, taught in an eminently practical fashion, appeals strongly to the apprentices.

Figure 10 illustrates a diploma of a graduate machinist and toolmaker apprentice and outlines the various classroom studies which he has successfully pursued. The boys are very proud of these certificates and the possession of one usually guarantees to them elsewhere good positions if they should leave the Company's employ.

The company is also concerned with the development of a certain amount of social life among the apprentices; it realizes that "all work and no play makes Jack a dull boy." One or two picnics in the summer, some dances during the winter, frequent informal meetings in the Apprentice Club-room, an annual dinner for the Apprentice Alumni Association are some of the recreational activities encouraged by the Company.

In presenting this brief description of some of the important features of the General Electric Company's apprenticeship system it has been my chief purpose to stimulate active interest in one of the most pressing needs of industry, namely, the effective training of an adequate supply of intelligent, skilled workers who will take pride in their work whether it is that of a mechanic or engineer, or that of an executive over mechanics and engineers. At the same time I hope to have made it clear that what has been done by one large corporation on a large scale can be done as effectively by smaller corporations on a correspondingly smaller scale. The same fundamental principles can be applied and the same effective results can be obtained; the smaller plants have simpler needs which can be accommodated by simpler organization and equipment. In making this positive statement I know of the satisfactory training results achieved by even comparatively small industrial establishments and by co-operation of several industrial establishments in the same locality. In the latter case one superintendent of apprentices has been given the power to supervise the practical apprentice training in a number of shops and to maintain joint classrooms for all these apprentices at a generally convenient place.

When an employer or his responsible assistant has once grasped the importance of training "for industry in industry" and has learned to understand the fundamental lines along which an effective system of training men must be developed, he will always find ways and means of translating his enthusiasm and determination into practical results.

C. R. Dooley: When apprentices have finished one or two years in the training room and are then passed out to other shop departments, do they stay in these departments

during the remainder of the apprenticeship or have they still further transfers during their regular course?

Mr. Alexander: Apprentices may be transferred to one or to several other departments after they have left the training room, according to what particular branch of the work they are trying to fit themselves for; the ability of the apprentice and the productive condition of the shop department are also controlling factors. Those who want to become toolmakers usually finish in the tool department, those who want to become diemakers in the die department, those who are being fitted for metal pattern makers in the metal pattern department, etc. As stated before, all apprentices, to whatever department assigned during their course, remain under the supervision and control of the superintendent of apprentices.

Mr. Friedlaender: Are boys specialized in one certain branch? For instance, if a boy wants to become a lathe hand, will he be trained so that he will be an expert lathe hand exclusively, without learning any other work?

Mr. Alexander: Apprentices are trained broadly for all-round skill in the particular branch of industrial work which they have chosen. Specialists, on the other hand, are trained only in one phase of industrial work. A man who wants to become a skilled lathe worker is therefore trained only in the effective and skillful handling of a lathe during a six-months specialist course. He may, however, take an additional or several additional six-months courses to learn also to operate a boring mill, a shaper, a milling machine, or to do other special work in an effective manner.

C. R. Dooley: I do not think I have ever been more instructed and entertained than I have in listening to Mr. Alexander. I have been through his Lynn plant. If you will allow me to underwrite every idea he has expressed and to tell you that insofar as we have had facilities at East Pittsburgh—you know we have not 65,000 men in our employ, but insofar as we can in a plant of 15,000 men, we are following out so nearly the program he has described that I wonder if he did not get his speech from our records. The training room, classroom and the ideals back of the training are very much like ours. They do differ in detail; however, I will leave the details of our work and only try to screw down a

little tighter the ideals he has set forth. They are absolutely right.

This question of education is not a matter of skill, text books, safety, or teachers; it is a matter of ideals of management, and these ideals I may sum up in two or three points; first, that every single employe has before him an open road to advance as far as his ability will permit, and, second, that each division head or executive consider himself a teacher, a trainer of the men under him. When we have reached these ideals, the name "Training Department" will pass off the sheet, and the names of General Electric Company, Westinghouse Electric & Manufacturing Co., and Carnegie Steel Company will in themselves mean a training work.

One point as to teaching. A division head should be a teacher. The teacher can do but three things for the student. There are some qualities of a good teacher which Mr. Alexander termed "God-given," and yet some of those can be acquired. Every division head, every executive worthy of his position can do these three things; first, assign definite responsibility and indicate the general trend of study that should parallel the execution of this responsibility; second, he can check the results with the standards that are acceptable to the industrial world; third, he can tell the student or employe exactly where he stands, where he has fallen below, and what others think of him. Recently one of my men came in to see me about his wages—he wanted a raise. I said to him: "if, as men go, your wage is a little below the average, we will boost it up, but you know and I know that the character of your work is not sufficiently stamped for me to allow you to feel that \$10 or \$15 increase means that you are all right." Then I went on to tell him one or two things wherein he was slipping. That fellow is now one of the happiest fellows you ever saw. He knows exactly the points he needs to eliminate, and that, to my mind, is the very best kind of an education. If, then, a division head sets the task clearly, checks the results frequently and then tells his men what he thinks of them, what they ought to do to improve, he will have rendered them the greatest service as a teacher that can possibly be rendered.

I will give you a brief outline of our program. Mr. Alexander has sketched four different lines of work; I am

only going to put in three. We do not have the high-school boy classified by himself. The drafting apprentices, the testers, the electric apprentices, the foreign and special students are classified in one group. The college men and summer teacher make the second group. Then comes that large third group Mr. Alexander referred to, between the ages of 21 and 35. The Casino Technical Night School, which is not only open to employes but to anyone who has ambition and a little money.

Casino Tech is adapted to men that have missed the apprenticeship period of life but that want now to obtain a training in fundamental principles. It is not a trades school, such as an apprentice school; and not a finishing school, as a college; but a sort of bridge to help the trades or shop man, who has ability, over into the engineering field. It costs \$20 to \$25 a year to attend. It is supported largely by the industries, to some extent by the community, and to a large extent by the tuition. Again, these three groups of men are; the young boy wanting a trade start; the technically trained men; and the group of fine, earnest working people that have not had a chance to get a training of any kind other than a mere mechanical skill in one line. And in all this work, from the lowest class—which, in the night school, includes the teaching of English to foreigners, the teaching of reading, writing and arithmetic to boys that ought to be in the public schools, on down through the whole system to the trained man that is being broken in as a designing engineer or a commodity salesman—the object is simply to make men think and grow and not to cram them full of information. Last year we had in the neighborhood of 1500 employes attending these various schools—some in the evening include girls learning cooking and sewing. Girls, winding coils in the shop, have advanced to office clerks and minor stenographers, and started on the up-grade as women fitted for the business life. All of the 75 teachers are employes—none of them special teachers.

When we have attained this ideal, these 1500 students will have expanded to 15,000 and the 75 teachers will have expanded to our whole executive force. Our whole group of employes will be going to school, in a sense. Our whole corps of executives will be teachers. Industry will thus at-

tain her maximum efficiency economically by providing abundant opportunity for each employe to grow individually to the limit of capacity. This is not only human kindness but good business. The two must survive or perish together.

The Casino Technical Night school has so impressed itself on the community that our public school district has appropriated money to assist in keeping it going, and within the last two weeks there was some very pointed discussion with officials of Carnegie Tech. and the City of Pittsburgh looking forward to the development of this type of work throughout the Pittsburgh district, feeling that possibly a chain of such institutions might be established to advantage.

I invite you all to come out and see us some time.

C. A. Menk: You have heard one who is your next-door neighbor. I had the pleasure of spending a day with the speaker, Mr. Dooley, a year ago. I do not think I ever put in a more profitable day. I even went so far as to send some boys out to him to train, and some day I expect them back.

Professor Dennison, of the Carnegie Institute of Technology, will give us a short talk on what his school is doing for us.

B. C. Dennison: In the splendid addresses to which we have listened, very little has been said about the technical graduate. One listening might get the idea that the technical graduate is not a very important part in either of the corporations represented. I do not believe this is the meaning the speakers meant to convey and they certainly have not at any time intimated as much.

With reference to the technical graduates, I feel like saying that at Carnegie Tech. we are not attempting to turn out iron and steel electrical engineers; and I hope that won't be a shock to you. I feel that if we were attempting to give a course in iron and steel electrical engineering, when these men reached graduation and you saw on the program that such and such were graduating from the course in iron and steel electrical engineering, you would say: "we don't want those fellows; give us somebody that hasn't this veneer; give us some fellows that have a thorough foundation in fundamentals; and we will take them out to our works and

teach them that particular phase which has to do with our own work. We will gain about six months, because we won't have to unteach them what they learned in college." And I think you would be largely right.

Moreover, the idea that a thorough foundation in fundamentals is to be preferred to any specialization in college has been emphasized very strongly of late by a number of men who have been to us for technical graduates. Mr. Allen of the Steel Foundries has been to us several successive years, has taken men, and because he comes back we feel they must be doing well. He says he does not care whether these men he takes have graduated from metallurgical engineering, mechanical engineering, electrical engineering, or some other form. He has taken men from at least four branches and put them in the same line of work, apparently with equal satisfaction.

I would say this: we are not attempting to specialize under-graduates in any one line of work. We have courses in Mechanical, Civil, Chemical, Commercial, Metallurgical and Electrical engineering, that is, we have those general divisions, but we are aiming to make men in each division rather grounded in the fundamentals which we realize they will meet in the work to which they may go, than specialists along the line of their chosen field. It would be interesting if I had the time to talk on the methods of segregation which we have in starting young men in the different engineering courses, and the effort we make, when we find they are wrongly placed, to get those men into other lines of work. Some men would make good lawyers, or perhaps should be clerks or business men rather than engineers; and we endeavor to get them into those lines of work for which they show aptitude.

I know the gentleman who is to follow me will tell you about a system his institution is following—the co-operative system—which they believe enables them to put the man more closely in touch with the industry during the time of his college course. We are not attempting to do the same thing, at least not in the same way. But we do urge the men to get into the industries during their vacations and we find at the end of each summer that nine men out of ten have done this. At the end of last summer it was found that of

the seniors in Electrical Engineering, sixteen out of the seventeen had worked during the vacation period (the seventeenth man had traveled) and had both added to their financial resources and good experience. Some had worked in steel-mills, some in electrical manufacturing, some as sub-station operators, and some in business positions. Those men had the advantage of hunting a job on their own initiative; had an opportunity to select according to their own preferences their own desired line of work. They had acquired the commercial and practical touch, and that is something which the system of summer employment is doing to a great degree, and we are not yet ready to surrender this system for some other.

In another way we are trying to give the men a knowledge of what a day's work is like. We have concentrated the shop work so that there is now given in three weeks at the end of the year a concentrated shop course of 8 hours a day, the students in the various years of their course working in the pattern shop, forge shop, machine shop, foundry, or even in bricklaying. They are getting some ideas that are entirely novel to them by the steady grind, eight hours per day, five days per week.

I want to say the fact that I knew so little about the Association of Iron & Steel Electrical Engineers is in part my fault and in part your fault. I believe that if we give our students a thorough grounding in the fundamentals of physics, chemistry, electricity, mathematics, strength of materials, and the like; if we do that and do it well, we can safely leave the rest to you. But you can help our courses by telling us what the faults of our curriculum are, and what the graduate may expect when he gets into the iron and steel industry. We have had but very little of the latter sort of suggestion except as it has come to us by a more or less hit and miss system.

Every year, during our week of inspection, we send groups of men out to the various industries. We have troubled many of you for the privilege of doing it, but the students have gotten some idea of what an electrical engineer may expect to find in a steel-mill and what the field may be for him, yet they have too narrow a view of what they may be expected to do if they go into your works. Many

feel, if they go into your end of steel-mill work, all they may expect is that they will have to do continual repairing of wornout machines in the roughest, quickest manner that may be available, just to keep things going; that the whole policy is laid out along steam and mechanical lines; that there is not much chance for them. Yet I have gotten the idea that this is not what you are doing and not what the future of the iron and steel electrical engineer is to be.

I think it would be useful if we could have one or two talks at Carnegie Tech. on iron and steel electrical engineering as a whole, on what the field is; by a man with electrical training. That is something that would help us. No teacher in our electrical departments is in position to give the viewpoint which you could bring, and it might be of advantage to you later.

In another way we can be of assistance to you. You doubtless know that at the Carnegie Institute of Technology we have night as well as day courses. The night and day courses cannot be the same, but we endeavor to give the night students almost anything they want. A great many students on special lines take only one year of work and it is possible for young men working for you to attend and if they want to specialize in electrical manufacturing they can take courses along that line. Or if they have the strength and ambition to take a five-year engineering course, that, of course, we are prepared to give. We are graduating only a few of the men who enter in the beginning of the five-year course. It is hard work and only a man who is very fit physically and can control his time judiciously can hope to finish the full night course. But your men can come to us and get something in one or two years at night; can take mathematics, economics, business administration, statistics; things which, in a business office, would be of great advantage.

We have also a School of Applied Industry, in which the students do not get an engineering course, but he does, however, get a careful training along the lines of what Mr. Doolley and Mr. Alexander have told us about in their apprentice courses. If a young man wants to take up machine work, he can get the theory of it and something of the practical as well, in the School of Applied Industry. We would gladly welcome you at any time at Tech., that you may get ac-

quainted with what we are doing. We want the young men under you to come also. Let them know they can come and the ways we can serve them. We are glad to serve you in every way possible and to help insure the future of the young iron and steel electrical engineer.

C. A. Menk: I have the pleasure of introducing our next speaker, Prof. Hallock of the University of Pittsburgh.

John W. Hallock: I will take no time to go into the matter of curriculum. At the University of Pittsburgh, the program is the same as you will find in numerous other engineering schools and universities throughout the country. As the preceding speaker has said, we differ in one respect; that we have a co-operative system, and it is no doubt that system which will prove more interesting than any other point that I might take up this evening. The co-operative system was introduced in the University of Pittsburgh in the spring of 1911. The object of the course, and I might add of the courses in engineering, is to turn out an engineer who is a finished product, not only in the theory of the subject, but also in the fundamental principles of the practice of that particular branch of engineering which he has chosen for his life-work. The arrangement of the course is such that the student receives the same amount of technical training as he would otherwise receive, and he is also required to spend four periods of three months each in the industries in and about Pittsburgh.

The arrangement is somewhat as follows: A man attends the university during his freshman year and for all of 9 months is in attendance at classes in the building. At the end of the first year, the class is divided into two sections; one goes out on factory work, the other remains in school for a continuation of the theory, and these two sections then alternate right through until the beginning of the senior year when all are in school for completion of theoretical work. During the freshman year, it is the duty of the instructor of this department, and one or two instructors who are working with him, to get in close touch with the student to size up his ability along engineering lines—I should say his adaptability, because about the first of the year there is a very serious weeding-out which results in a smaller class taking the work. This weeding-out process continues dur-

ing the second semester. The instructors are in close touch with men in the shops and with the men in the laboratories and class-rooms, so that the man who shows he can take the course and who has the greatest personal efficiency in industry, is the man who in co-operative work is the first and foremost in the minds of the instructor for the best job we have.

The term co-operative needs a little definition. We are endeavoring to turn out for you, men whom you can later assimilate; either in engineering departments, or in positions in shops or office business-managers; men whom you can take right now and assist for four terms as they receive their theory. In the end when they are graduated, they naturally turn to you for further guidance in taking up the serious part of their life work.

At the present time the class in engineering numbers approximately 277 students, which is a small school. We could not make it much more than 277 at the present time, on account of lack of equipment and lack of space, but we hope to expand and increase the number.

You are not concerned, I presume with the details of the management of this particular phase of the work; but as to your side of the question, you might naturally ask me, "Is it difficult to find places to put these men?" I will say, "Yes, it is; that is to find proper places." Even with business as it is today with foremen clamoring and crying for men, men of just such caliber as our engineering students. Then we have another difficulty in placing men, but it is a difficulty we ourselves create. We create it for the benefit of the student. For instance, let me give you one example: Here is a man who has ability in his freshman year, his work in the shop has been entirely satisfactory, he shows a very great aptitude for chemistry and metallurgy, and we select him at once for the steel foundry, or for some branch of foundry work. The particular man I refer to we placed with the Lewis Foundry & Machine Company, worked with the metallurgist in the laboratory half a day, and in the shop half a day, or, perhaps, two hours a day in observing the general methods of that particular firm. That man, we know, is well placed. But, we might have placed him in another steel foundry, where he would have done one thing and have no

particular attention paid to him, and the result we would attain with this particular man would never have been right. The result I refer to was this: They understood that he was a Junior and would only have one or more year of school before they could employ him permanently. Instead of that he had three, and the firm was very much disappointed over the delay. Then there were lots of firms who say we would like to take care of you, but we cannot take your apprentices and pay any attention to him; we don't have educational facilities such as the Edison Company or the Bell Telephone Company, and, therefore we can't take your man.

Now at the present time, the situation, as I say, is in placing with various firms students who may develop naturally along that particular line of work. Then, by continuing with that firm during his co-operative work, the firm can size up that man and his associates and endeavor to place him in some line of engineering work in that particular branch he has chosen, so that later on he may be an efficient and industrious employee.

The result of a man having this practical work and of being so directed into this channel or that channel has been that a great many men have been directed away from all these channels, and, as Professor Denniston has said, into some other branch of work in which they are more eminently fitted. The mortality rate will, I trust in the next five years not be much greater than ever before, but I hope it will lead to a repetition of many instances such as this year has brought us when every single one of our graduates was signed, sealed and delivered for some job or other fully two or three weeks before closing time, and there were about 60 of them. I might go further and tell you how we handle these men and how we keep in touch with firms for whom they work and how we grade them, but these are details in which you would hardly be interested.

I would like to second the remarks Mr. Dennison has made, that we want to be of further service to you. Many of you have been of great service to us in co-operative work. We want to produce engineers whom you can place in any one branch of your business for which you have specifically trained them, and we want you in turn to co-operate with us to produce such engineers. We want to hear from you many

times over during the year. The complain is often made that the average student in co-operative course drops out of sight of the practical points he ought to absorb during his course. If many of you men would do, as men in other branches are doing, come to the University and meet them between classes, in classes, in halls, everywhere, then those men would be more alive to the situation in the engineering world. I certainly appreciate the opportunity of being here tonight and getting in touch with this organization, and hope in years to come we may more and more accomplish, not what the University wants, but what you men want and need.

C. A. Menk: We appreciate the talk of Professor Hallock, and believe we can do a great deal for the University. I think that is the right thing. I see it is a hard matter in placing the men they turn out. In a great many cases, we run against an obstacle that is hard to overcome. In some cases, after young fellows go to the University and Technical Schools, they come out feeling that they have graduated and that should carry them through life, but it is really only the beginning. We find in many cases they flatly refuse to do any work. Other cases are different; so you see it depends a great deal on the man, and on the way they treat us. Just an instance; a few years ago, we took two or three men—I believe they came from Tech. We gave them good positions and what we considered pretty fair pay. We obtained only three or four months' work out of them and they left, so they didn't give us very much encouragement. But if you get hold of the right men, there is great future for them.

The next part of our program will be an outline of the educational work as carried on at the present time at Homestead Steel Works. Mr. Wolf will give us the outline of the work they are doing and of which he is in charge.

A. Francis Wolf: If any of those present had the privilege of attending the convention of the National Association of Corporation Schools, held recently in Pittsburgh, they must have been greatly impressed by the magnitude of the educational movement now under way in all parts of the United States. The combined capital represented at this convention was estimated by one of the speakers at about three billion dollars. At least one of the delegates came all

the way from Sacramento, Cal., to attend this convention. It is thus seen that there is a widespread interest manifested by the large employers of labor in the object of this Association, as stated in their constitution, namely, "To aid corporations in the education of their employees." In order to give you some idea as to how this work is being done by one of the members of this association, I will give you a brief description of the Trades Apprentice School as carried on by the Carnegie Steel Company at its Homestead Plant. Similar schools are conducted at some of the other plants of this company, but are managed in somewhat different ways. It is hoped, eventually, I believe, to establish a uniform system for these schools throughout the corporation, when one is developed that will meet the peculiar needs of the steel making industry.

In addition to the Trades Apprentice School, the company conducts a school for salesmen and post graduates.

The Trades Apprentice School at Homestead Steel Works was started November 3, 1913, for the purpose of improving and extending the apprenticeship system then in existence. The men placed in charge of the organization and development of this school were from the Mechanical Engineering Department of the plant and had had some previous experience in teaching the evening classes in mechanical drawing at the Homestead Carnegie Library. The school was started with the idea of teaching the apprentices to read blue-prints, to make free-hand sketches and to apply their public school education to problems in the shops. The fifty-five apprentices with which the school was started represented ten different trades as follows: General Machinists, Pattern Makers, Carpenters, Blacksmiths, Foundrymen, Bricklayers, Pipe Fitters, Painters, Tinsmiths and Electrical Machinists, and ranged in school work from the fourth grade in the public school many years ago, to the recent High school Graduate. The average school work was equivalent to about 6½ grades.

The instruction in the apprentice course can properly be said to come under two general heads. First—that received in the shops. Second—that given in the school room. The time the apprentices receive instruction in the school room is only about 6% of that spent in the shop and they are

paid at the same rate in both places. The instruction in the shops is in charge of shop advisors who answer questions of the apprentices and otherwise instruct them. The instruction in the school is carried on by means of classes under instructors, who are "part time" teachers and are employed in the mechanical engineering department during the balance of the day. It is considered a necessary qualification of these teachers that they should have received a part of their training in the shops.

No mental examination was given the original members of the school, as they had been taken on under the old system and could not well be eliminated. Many of them held their positions through influence, or because it was thought necessary to take care of them for charitable reasons. This seemed wrong from the standpoint of efficiency and it was decided that a boy should have at least the equivalent of seven grades in the public school before he could enter the classes. A written test is now given which consists of a few simple problems in fractions, decimals, percentage and mensuration. About 75% of the applicants pass this test without any trouble. Some of those who fail to pass the first test are given a second chance after having had an opportunity to review their school work. Others who are finally unable to come up to the requirements of the school, but of whom it seems necessary for the company to take care (for the reason stated above) are given other positions around the plant which do not require the skill or technical knowledge of the tradesman.

The apprentices attend school three and one-half hours a week, which is equally divided between mechanical drawing and shop problems. The classes in shop problems are divided into three grades at present, and a new apprentice is generally started in the lower grade and kept there until the instructors have a chance to see what he can do. Some never reach the higher grades at all, while others advance very rapidly until they reach the highest class.

The work in the lower grades comprise the fundamentals of arithmetic, mechanics, trigonometry, physics and chemistry, insofar as the need of these subjects, by the tradesmen, can be seen. The work of the upper class is very general in character and is based on periodical trips

through the various shops and mills of our own and nearby plants. This scheme is best illustrated by means of two circles, one of which is filled completely with the first year's work, which comprises the elementary work in arithmetic, physics, mechanics, etc. The second circle is divided into three equal parts (the three remaining years of the course) these parts are again divided into quarters, into which are written the schedules of the mill trips. This arrangement takes care of the apprentice entering at any time during the four years, as he will be in the classes during the complete cycle of the course if he remains the three years after reaching the higher classes.

During the mill trips, experts from the departments visited usually accompany the class to explain the operation and uses of the various machines and devices, and generally the co-operation of the mill superintendents is cheerfully granted in arranging for these trips. After one of these trips the apprentices are required to write an essay, telling what they have seen and heard. These essays are read aloud and criticized in class. Note-books are also given the boys with the understanding that they are to hand them in for inspection at any time requested. The subjects of the notes made in these books are left almost entirely to the discretion of the apprentices, and they are allowed to use these books during the written tests, which are held every four months. In this way it is hoped to develop their ability to select the useful data and to express their thoughts in writing and sketches.

The work of the mechanical drawing classes is made to conform to the shop practice of the apprentice wherever possible, and drawing room methods are used in making sketches and drawings.

In the selection of problems for the other classes, it is always desirable to make them apply to the shop work.

No home work is required of the apprentices at present but the inclination on the part of the apprentice to do home work is encouraged in every way possible. One way in which this is done is to loan drawing boards to those who want them. Another way is by reference to books and magazines in the library on subjects under discussion in the

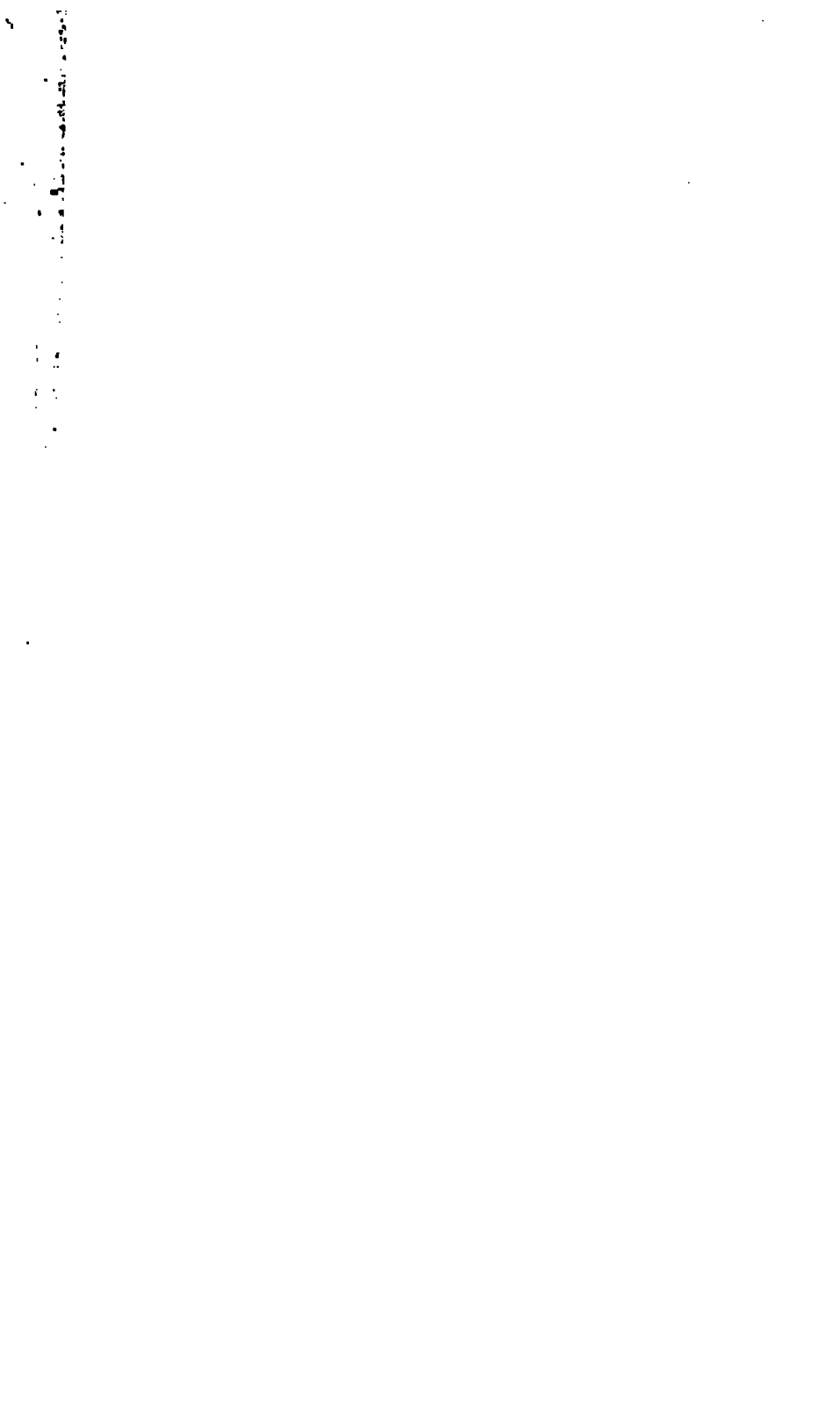
classes. There are quite a few of the boys who take advantage of these opportunities.

In conclusion I wish to say that there is no doubt a great deal of good being done in this school; not only in the instruction given, but in the opportunity it affords those who have not had a previous opportunity to learn the value of school training in its practical application. Quite a number of our students have decided to enter the Tech night school and not a few do home work and attend the Homestead Library evening classes. The work in the school is a means of bringing these boys together and is thus of great value to the organization as it is a well-known fact that school life cements lasting friendships.

W. T. Snyder: I believe you will agree with me that we have had quite an educational treat this evening. The series of meetings held in Pittsburgh this year have been very interesting, and this meeting has been as interesting and educational as any that have been held by this or any other Association. I congratulate the Educational Committee on the very excellent program they have provided this evening.

It is with deep regret that I have to announce that death has removed from our ranks a valuable member and an estimable gentleman, Mr. C. G. Rally, of the Power and Mining Department of the General Electric Company, Schenectady.

This will be the last meeting until after the summer months, and we rather dislike to see the meetings stop; since they seemed to be increasing in interest.



THE OPERATION OF MECHANICALLY-CONNECTED DIRECT-CURRENT MOTORS PERMANENTLY IN SERIES OR PERMANENTLY IN PARALLEL

BY H. F. STRATTON

In this paper, reference will frequently be made to two or more motors mechanically connected; I will define the phrase "mechanically connected" as meaning first, that any change in speed of rotation of any one motor must be accompanied by the same proportionate change in speed of rotation of each of the other motors, and second, that a change in the direction of rotation of any motor must be accompanied by a change in direction of rotation of each of the other motors.

This definition is made broad enough to include the infrequent cases where two or more motors of different horsepower and speeds are operating together to drive one motion, and the more frequent cases where the motors may be identical in horsepower and speed but may rotate in opposite directions. The majority of cases claiming our attention will include two or more motors of the same horsepower and speed, all rotating in the same direction at the same time. The mechanical connection between motors may consist of gearing, pulleys and belts, sheaves and cables, or it may be through track and track-wheels as on the bridge motion of a traveling crane.

Electric cars furnish an early example of two motors mechanically connected. One reason for their use in this work was the small clearance between the track and the bottom of the car; another reason was the economy in power consumption which was gained by the use of series-parallel control.

The steel mills furnish frequent illustrations of two or more mechanically connected motors, and it is logical to inquire why preference is given to several mechanically connected motors instead of one large motor having a horsepower rating equivalent to the sum of the smaller motors.

In some cases, two or more motors have been used simply because it was handy. It may be that the frame of the smaller motors fitted more easily in the available space or that it appeared to be considerably easier to change armatures.

Sometimes the horsepower requirements are quite large, and if one large motor instead of several small ones, were used, it might introduce into the mill an entirely new size of motor, thereby complicating the spare part situation; or the horsepower rating might be beyond the range of mill type motors, thereby forcing the use of a motor which did not seem to have the same sturdy qualities that characterize mill type motors.

Another reason, and a very good one, for the use of two or more mechanically connected motors, is the need of continuing to operate some machine, even if one of the motors burns out. In this case the remaining motor, or motors, are made of sufficient capacity to maintain operation, although perhaps at a reduced speed. A metal mixer is a good illustration of a machine coming under this classification, as it is obviously necessary to be able to tilt the mixer even if one motor is disabled. The hoist on a ladle crane is another common illustration of the same character.

It has come to my attention several times that two or more mechanically connected motors have been selected for a roller table service on the theory that the small motors will accelerate and reverse more rapidly than one large motor, and that therefore a roller table so equipped, has a larger capacity to move steel. Probably this belief was based on the fact that so far as mill type motors are concerned, the moment of inertia generally increases a little more rapidly than the horsepower rating. For instance, the moment of inertia of the armature of a 25 horsepower motor is apt to be less than one-half the moment of inertia of the armature of a 50 horsepower motor. There is an

error or omission in this reasoning to which I shall refer later.

I have also heard the use of two mechanically connected motors permanently in series, advocated for roller table service on the theory that acceleration or reversal was as rapid up to half speed as in the case of one or more motors receiving full line voltage, but with the added advantage that the two motors in series did not have the same tendency to race if allowed to run for a length of time. It was

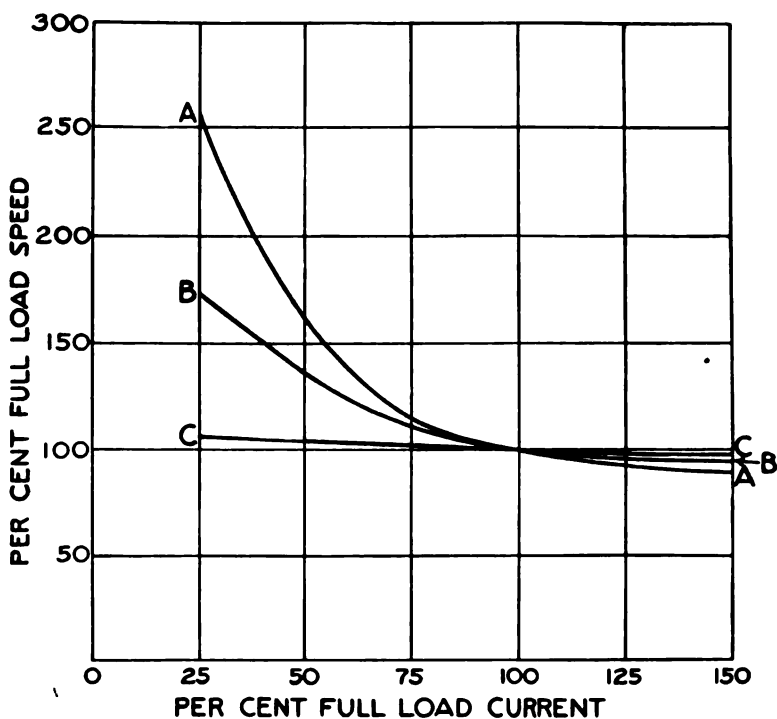


FIG. I

felt that this made reversing quicker and easier for the motors. I have also known cases where steel mill engineers have felt that there should be a worth while saving in the cost of the controller for two motors mechanically connected and permanently in series.

The foregoing illustrations are those which have come to my attention from time to time favoring the use of two or more mechanically connected motors in the place of one

large motor, and no doubt other reasons could be stated. This practice, however, has raised new difficulties, some of which can easily be explained by theoretical considerations; others, however, are brought to our attention forcibly only by the difficulties experienced in service and sometimes it is puzzling to find the true explanation of the difficulties which have developed. I suggest that we consider first the electrical problems which are very largely the questions of circulating currents and the unequal division of the total motor current.

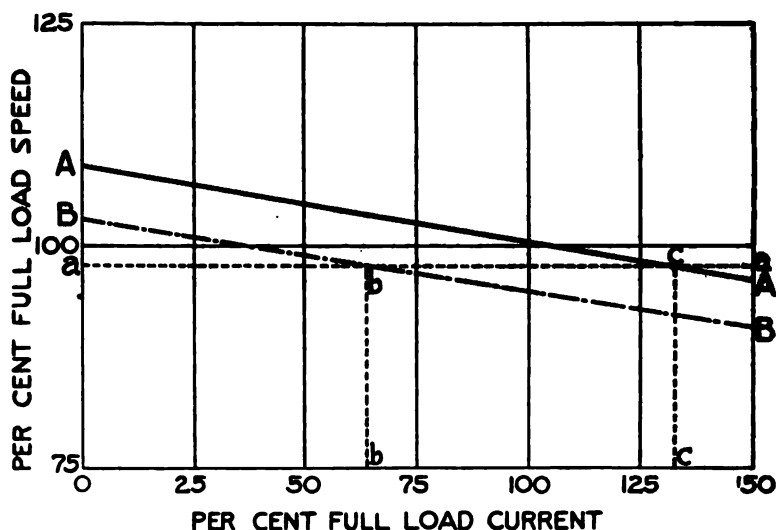


FIG. 2

The following is the general equation of a direct current motor: The speed of rotation is equal to the voltage divided by the product of the number of effective armature conductors and the amount of magnetic flux which is cut by these conductors. The characteristic curves of series, shunt and compound motors are merely graphic illustrations of this fundamental equation bringing in, in addition, the variation of motor current as a function of speed and the variation of torque as a function of current. It will be more in line with our purpose to show curves for series, shunt, and compound motors, illustrating the change in mo-

tor current with change in speed. It is, of course, well known that the speed changes least in the case of shunt motors, more in the case of compound motors, and most in the case of series motors.

In Fig. 1, curve AA represents the relation between speed and current in the case of a series motor, BB in the case of a compound motor, and CC in the case of a shunt motor. These are curves expressing current as a function

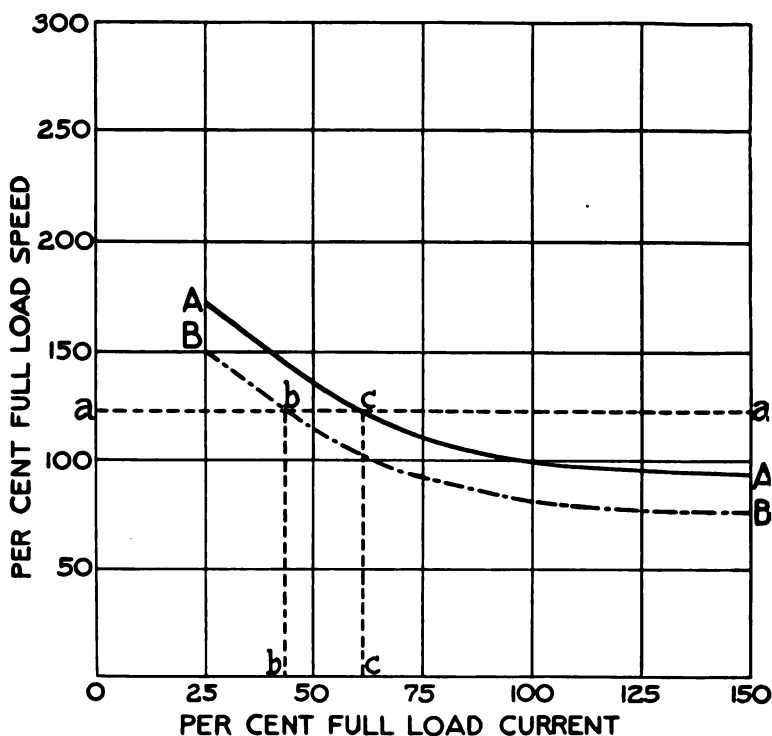


FIG. 3

of speed; it must be remembered that such a curve represents only approximately the performance of any given motor, and as a matter of fact the speed-current curves of different motors—although built commercially to be duplicates—will vary by several per cent. Take the case of any standard motor; undoubtedly all such motors built from the same drawings and patterns will have the same gener-

al physical dimensions, the same number of effective armature conductors, and the same number of turns in the field coils. It must be remembered, however, that the position of the speed-current curve is strongly affected by the total flux which is cut by the armature conductors. In each case the voltage may be the same, the armature and the field coils may be the same, but the total flux may vary consider-

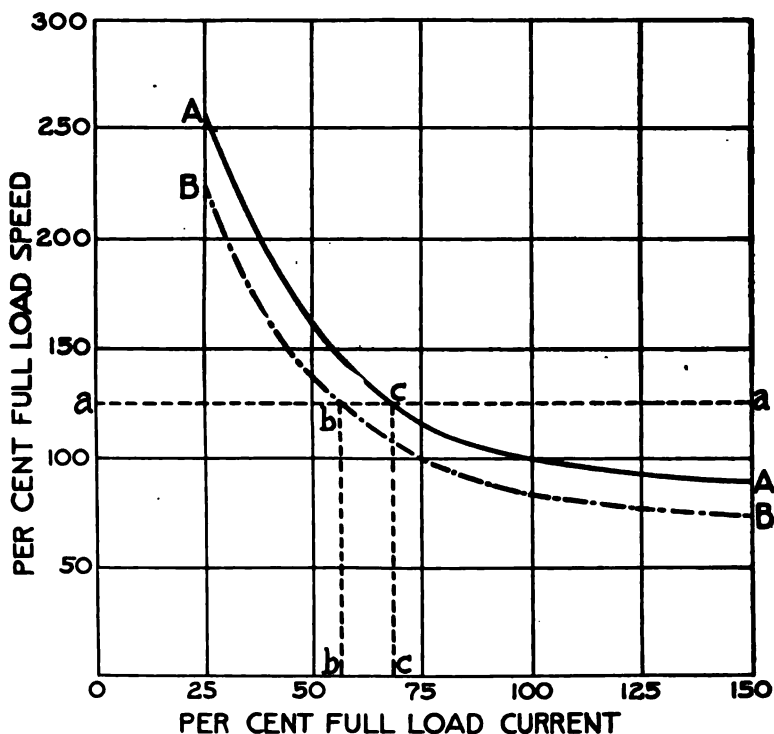


FIG.4

ably, because the reluctance of the iron circuit of the motor will depend on the character of iron employed and upon the lengths of the several air gaps.

In Fig. 2 the full line AA is the speed-current curve of one shunt motor, the dash line BB the speed-current curve of another shunt motor which might be easily sold as a duplicate of the first named motor. The only differ-

ence between these two curves is that at any given load, one of the motors has a speed 5% in excess of the other motor. If two such motors are connected to a machine so that they must rotate at the same speed, there will necessarily be a heavy unbalancing of the total current. For instance, assume the load is such that the two motors will run at the speed indicated by the line aa; it will be seen from the diagram that one motor will then take 65% full load current and the other motor 135% full load current. The two motors together are taking twice the full load current of one motor, but one motor is considerably underloaded and the other motor so much overloaded that it will burn out if the load is maintained.

Fig. 3 indicates the conditions which might be expected in the case of a compound motor and Fig. 4, the conditions

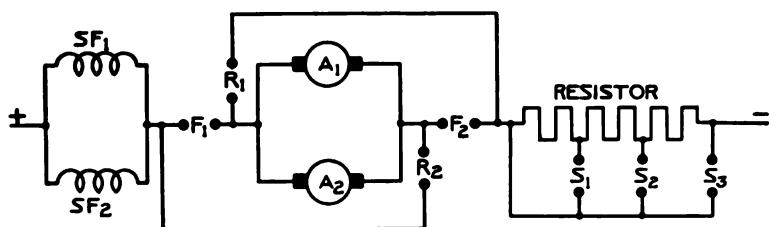


FIG.5

in the case of series motors. It will be noted that the unbalancing of mechanically connected series motors will be less than the unbalancing of either shunt or compound motors. The unbalancing of compound and series motors is least at high speed and low current and greatest at low speeds and high current.

So far we have not considered the question of control, but have merely reached the conclusion that, due to imperfections in motor manufacture, two or more mechanically connected motors are apt to divide the load unequally, and that this difficulty is least serious with series motors, more serious with compound motors, and most serious with shunt motors. Several other causes might lead to similar variations in the speed-current curves. Examples: unequal heating of shunt field coils, failure to rewind armature or

field coils with the original number of turns, poor condition of commutator or brushes, or greater drop in line voltage in leads to one motor than in leads to another motor. In short, there are many reasons why two or more mechanically connected motors—nominally duplicates—will make an unequal division of the total motor current.

Two series motors are sometimes controlled by a single, standard, one-motor controller by connecting the two series fields permanently in parallel and the two armatures permanently in parallel. Fig. 5 represents such a condition wherein SF_1 is the series field of one motor, SF_2 is the series field of the other motor, A_1 is the armature of one motor. A_2 is the armature of the other motor, F_1 and F_2 are one pair of reversing contactors, and R_1 and R_2 are the other pair of reversing contactors. S_1 , S_2 , and S_3 are the acceleration contactors which are used for short-circuiting

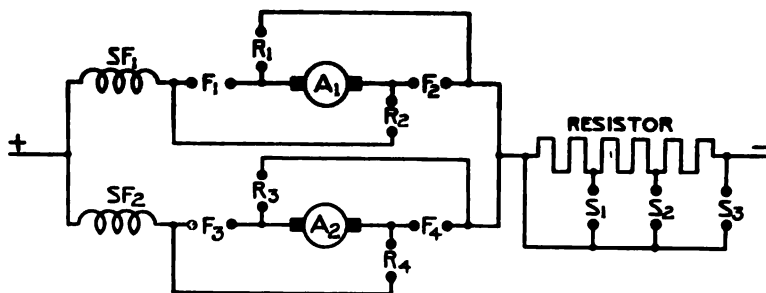


FIG. 6

the resistor. The entire motor current flows through the two series fields in parallel, which are of relatively low resistance; as the current will divide inversely as the resistance of the two fields, it is a delicate and difficult matter to balance these two circuits so that they shall divide the current equally, not only when the motors are cold but also when they are hot. The general result is that more current flows through the series field of one motor than through the series field of the other motor. The motor having the smaller portion of current through its series field will have less total flux to be cut by the armature conductors; it will therefore develop less counter-electromotive force than the other motor, and will permit a considerably higher current

to pass through its armature. The motors will, therefore, be unbalanced, not only because of imperfections in manufacture, as shown in Fig. 4, but in addition and more seriously, because the total flux of one motor will be larger than the total flux of the other motor. The conclusion of this analysis is, therefore, that the operation of two mechanically connected series motors by one controller may lead to serious unbalancing of the current.

The first departure from this scheme of control is one probably suggested by the practice followed on electric cars. Here it is usual to employ one starting resistor, but to have individual reversing switches for each motor. These connections are shown in Fig. 6, wherein the designations are the same as in Fig. 5, with the exception that F_3 , F_4 , R_3 ,

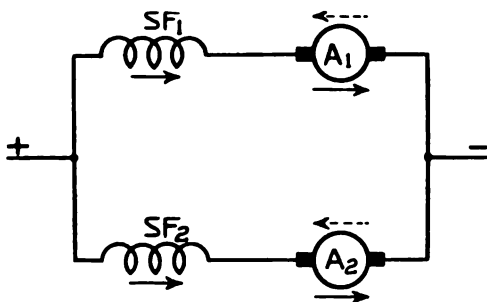


FIG. 7

and R_4 represent an additional set of reversing contactors. With individual reverses for each motor, it is possible to connect the series field of one motor directly to its armature and the series field of the other motor directly to its armature. This connection eliminates the unbalancing due to unequal division of current through the series field, as explained in connection with Fig. 5. It is a satisfactory connection for two mechanically connected series motors when these motors are merely started from rest and accelerated to receive full line voltage. The only unbalancing of load is that due to variations in the speed-current characteristics of the two motors.

I have said that the connections in Fig. 6 are satisfactory for accelerating the motors from rest to full speed.

They are not satisfactory for rapid reversing or "plugglug," the difficulty being one of circulating currents at the moment of reversing.

Fig. 7 indicates two mechanically connected motors operated by this scheme of control and receiving full line voltage. The current passing through the series field and the armature of each motor is indicated by solid arrows and the counter-electromotive force developed in each armature is opposite in direction and is indicated by the dotted arrows. Assume that these motors are running at full speed and that the controller is reversed, whereupon the connections in Fig. 8 are immediately established. The direction of current through the series field remains the same; the armatures are still rotating in the same direction,

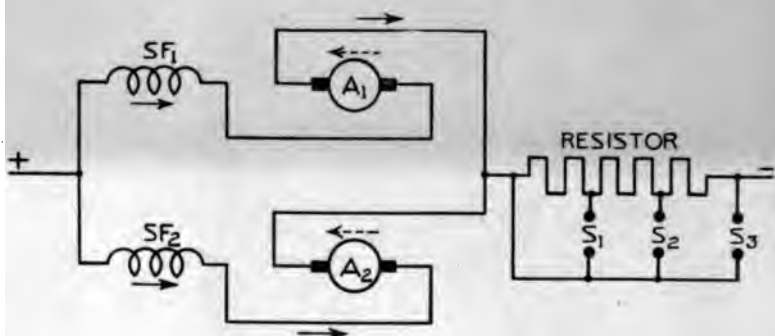


FIG. 8

and therefore, the direction of the counter-electromotive force remains the same; but the connections between the armature and the series field of each motor have been reversed so that now the direction of the current through the series field and the direction of the counter-electromotive force of each motor, are the same. The series fields and the armatures are connected in a closed path, of which the resistance is relatively very low. If the starting resistor is designed to allow the passage of 50% overload at reversal, the counter-electromotive force developed in each armature is somewhat in excess of line voltage. Each armature may be looked upon as a booster assisting line voltage to force current through its series field. The counter-electromotive

force of one motor will probably be at least slightly greater than the counter-electromotive force of the other motor. For illustration, assume 250 and 240 volts for the top and bottom motors respectively. With this condition more current will pass through the series field of the top motor than through the series field of the bottom motor. The effect of this will be to further increase the counter-electromotive force of the top motor and further decrease that of the bottom motor. The fields become still further unbalanced, and presently, due to the predominance of the top motor, a local current circulates through the series fields and armatures of the two motors, reversing the series field of the bottom motor. As soon as this is reversed, the direction of the

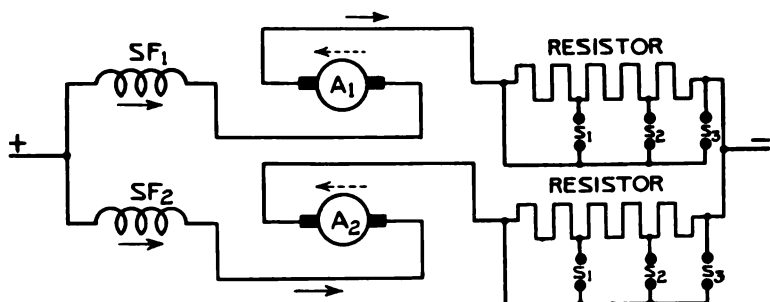


FIG.9

counter-electromotive force of the bottom motor is reversed, and we then have two series generators in series with each other generating current in the same direction with no external resistance in the circuit. The result is, of course, an amount of current which is not only inconvenient but positively dangerous. We, therefore, reach the conclusion that where only one acceleration resistor is used, it is advantageous to identify each series field with its armature in starting from rest, but that on rapid reversal these connections are dangerous, and should not be employed.

The circulating currents described are prevented by employing the connections shown in Fig. 9. This differs from Fig. 8 only by having an individual acceleration resistor for each motor. The local path through which the circulating currents flowed has now been made to include such high

total resistance that the circulating currents cannot get started and with these connections, rapid reversal is smooth and normal.

This analysis might be expanded almost indefinitely by investigating other more complicated methods of control, such as dynamic braking hoist controllers, armature shunts, etc. I will have to dismiss this additional subject with the statement that the more complicated forms of control contain even greater dangers of unbalanced loading and circulating currents.

Fig. 9, which has been reached by the elimination of all the previous diagrams, is, in my judgment, the only satisfactory way to control two or more mechanically connected motors permanently in parallel. This diagram represents

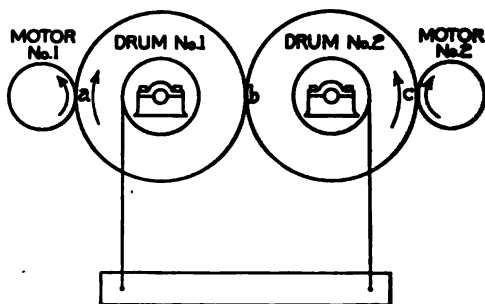


FIG.10

in reality, a controller for each motor. In order that the controllers should function simultaneously, it is preferable to use two-pole contactors for two motors, three-pole contactors for three motors, etc. This assures that all important circuit changes, such as reversal or short-circuiting portions of the acceleration resistors, shall occur at the same time in each motor circuit.

Fig. 10 represents an interesting example of unbalancing, not of current, but of braking effort. This represents diagrammatically the hoist of a ladle crane, with the motors No. 1 and No. 2 permanently in parallel and geared, as indicated, to the hoisting drums No. 1 and No. 2. Each motor was equipped with a magnetic brake, but, due probably to unequal adjustment, one brake would act more quickly

than the other after the cessation of current through its coil. Assume the ladle is being hoisted, in which case the motors and drums would rotate as indicated by the arrow. Suppose now that the controller is brought to the "off" position, but that the brake on motor No. 2 locks the armature of that motor before the brake on motor No. 1 locks the armature of its motor. In this case the point c must remain stationary, but motor No. 1 exerts a force upward on the drum No. 1 at point a. This produces a downward thrust at the point b on the drum No. 2, but as the mechanism is rigid in this direction, drum No. 2 does not move. The result is that drum No. 1 tries to rotate upward about the point b. The bearing caps, while of liberal proportions, were probably not designed to take an upward thrust, since it would appear that the weight of the ladle would always keep the drums resting heavily on their bearings. The final result was that the bolts holding down the bearing caps of drum No. 1, were stretched or broken. In this particular mechanism, if one brake locks before the other, there is always a tendency to lift one of the drums, no matter which brake locks first, and no matter whether the load is being hoisted or lowered. This is an actual difficulty which has occurred in several instances, and I believe has led to the use of larger cap bolts.

Generally speaking and within reasonable limits, the larger the motor, the greater will be the number of acceleration contactors employed in the controller. For instance, in rapid reversing controllers, it is common practice to employ three acceleration contactors for a 50 h.p. motor and four for a 100 h.p. motor. With two mechanically connected motors permanently in parallel, the question arises whether the number of acceleration contactors should be determined by the horsepower of the individual motors or by the total horsepower; or to put the question concretely, should three or four acceleration contactors be employed in the case of two mechanically connected 50 horsepower motors. Probably the best way to find an answer to this question is first to decide why we use more acceleration contactors with large motors than with small motors. One reason is to flatten out the acceleration curve so that the current peaks will not be so large. A current peak of 175% on a

500 h.p. motor might cause serious line disturbance, whereas a similar overload of a 25 h.p. would be negligible as far as line disturbance is concerned. I think this point is more hypothetical than real in the case of the average motors employed in a steel mill as there is usually ample generator and line capacity. Another consideration is that a small motor generally commutates high current peaks better than a large motor. Perhaps the leading reason for increasing the number of acceleration contactors on large motors is to get a characteristic which it is hard to describe and which I will call controllability. It is usually satisfactory if a small motor accelerates from rest to full speed almost before the operator is aware of it, but in the case of large motors, operating heavy and important machines, the operator must have more sensitive and responsive control over the starting and reversing of the motor. Bearing these three

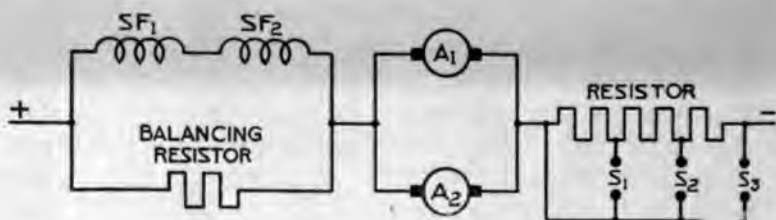


FIG.11

thoughts in mind, it seems to me the number of acceleration contactors can be determined somewhat in the following manner: If the motion is merely one of rapid reversal, and line disturbances need not be considered, select the number of acceleration contactors from the standpoint of the size of one motor; if the question of line disturbances is important or if you are concerned with the controllability of the machine, select the number of acceleration contactors from the standpoint of the total horsepower.

There is time to discuss only very briefly a few of the many changes in the controller itself, which have been suggested for the control of mechanically connected motors in parallel.

Fig. 11 represents a scheme for controlling two motors with one set of reversers and one acceleration resistor.

The two fields are in series with each other and in parallel with a balancing resistor. This connection assures the same current in each of the series fields, but there is no assurance that the correct amount of current will flow through the series fields. In installing a controller of this kind, cast grid resistors are generally used for the balancing resistor, having a cold ohmic resistance equal to the cold ohmic resistance of the two fields in series. During operation the balancing resistor and the fields both become heated, but the change in resistance will probably be unequal, inasmuch as they have different temperature-resistance coefficients and probably different current capacities. Consequently the series fields receive considerably more or less than half of the total motor current, leading respectively to overheating or diminished torque. It is almost impossible to divide the current equally, at all temperatures, between two low resistance paths in parallel.

When it is necessary to insure uninterrupted operation of a machine driven by several motors some engineers have preferred an entirely separate controller for each motor rather than the two-pole or three-pole controller which I have advocated. They have argued that in the event of an overload, both motors were stopped with the double-pole method of control, but with separate controllers, only one motor was stopped. As a modern controller can be reset in one or two seconds after operation of the overload device, I do not feel that this is a serious objection. Another argument has been that if a control circuit or an operating magnet failed on a double-pole controller, then the entire controller was temporarily useless, whereas with the same accident with two entirely separate controllers, the undamaged controller could be maintained in operation. There is some merit to this contention, but an argument against it, is that there are just twice as many coils and control circuits on the two separate controllers as there are on the one double-pole controller.

With two separate controllers there is no certainty that the important circuit changes will occur in each motor circuit at precisely the same time. There is danger, therefore, of unbalancing and of circulating currents, although it is true that these will exist for only a brief period of time.

They constitute a menace, however, which, in my opinion, should weigh heavier as a possible cause of motor trouble than the two arguments which I have mentioned above as favoring the use of an individual controller for each motor.

The previous discussion having dealt exclusively with motors permanently in parallel, I suggest we next consider motors permanently in series. If two motors are permanently in series, they of course, require only the amount of current normally demanded by one motor of the same size. Each motor exerts full torque up to half speed, but at any greater speed the performance of two motors permanently in series is entirely different from the performance of two motors permanently in parallel. Two motors permanently in series will have a diminishing torque, whereas two motors permanently in parallel can maintain full torque up to full speed. This has sometimes been considered an advantage for roller table service. The line of thought has been that the important consideration is the reversing and acceleration up to perhaps half speed, and that it was a positive advantage if the motors did not have so much disposition to race if allowed to run in one direction for a considerable period of time. I have known of two or three mill tables where parallel connections were first tried for a while and where later, series connections were substituted. By changing to series connections it was found that the motors did not race so much and that reversal was made easier. It was found, however, that the table was slowed down some, or in other words, did not have as large a capacity to move steel. Of course, with motors permanently in series there is no danger of circulating currents of unbalanced load. The mechanical connection precludes the possibility of one motor reaching high speed while the other motor slows down, which would be a real hazard if the motors were free to run at different speeds. Therefore, from an electrical standpoint, permanent series connections must be regarded as satisfactory.

It is probably pertinent to inject here a brief discussion of the controller for motors permanently in series. So far as its capacity to carry current is concerned, this can be decided from the standpoint of the size of one of the motors. However, the heating of the reversing contactors and

the line contactor is due more to the arcing at the contacts than to the passage of current when the contactors are closed. The heat developed by an arc is largely determined by the persistence with which the current endeavors to flow when the circuit is opened. It is the inductive quality of the circuits to be interrupted which largely decides the severity of the arc at the point of interruption. In the case of a series motor, this inductive effect is represented mostly by the series field, and with two series fields in series, there results a much hotter arc than with only one series field. Therefore, it is erroneous to determine the size of arcing contactors for motors permanently in series, from the horsepower rating of only one motor.

Another consideration is the amount of resistors that must be supplied. If two motors in series reach full speed and are then suddenly reversed, there is a voltage at the moment of reversal, equal to the sum of the line voltage, the counter-electromotive force of one motor, and the counter-electromotive force of the other motor. Roughly speaking, this is about three times line voltage, which demands more resistors for reversal than in the case of one motor.

Earlier in the paper I mentioned the belief held by some that it is easier to accelerate two motors than one motor having a rating equivalent to the sum of the two motors. I have made a rather thorough investigation of mill type motors to determine in a variety of cases, the time required to accelerate the armature from standstill to rated full load speed, supplying the motor with the usual acceleration current. Although in some cases the moment of inertia of the armature increases more rapidly than the horsepower rating, yet this is more than overcome by the fact that the normal full load speed is less in the case of the larger motors. I cannot find any support of the theory that a small motor can be accelerated to full load speed more rapidly than a large motor, assuming in each case the usual acceleration current and taking account of the fact that the normal speed of large motors is less than small motors.

I am able to present to you some current curves of two mechanically connected motors permanently in parallel; these records were made by a double recording ammeter built specifically for this investigation and capable of indicat-

ing graphically the simultaneous variations of current in two entirely separate circuits. So far as I know they are the first curves of this kind which have been made. Each figure shows the current changes in the two different motors and for brevity I shall refer to them as the top and bottom motors, meaning thereby, the motors, the curves of which are shown respectively at the top and bottom of the figures.

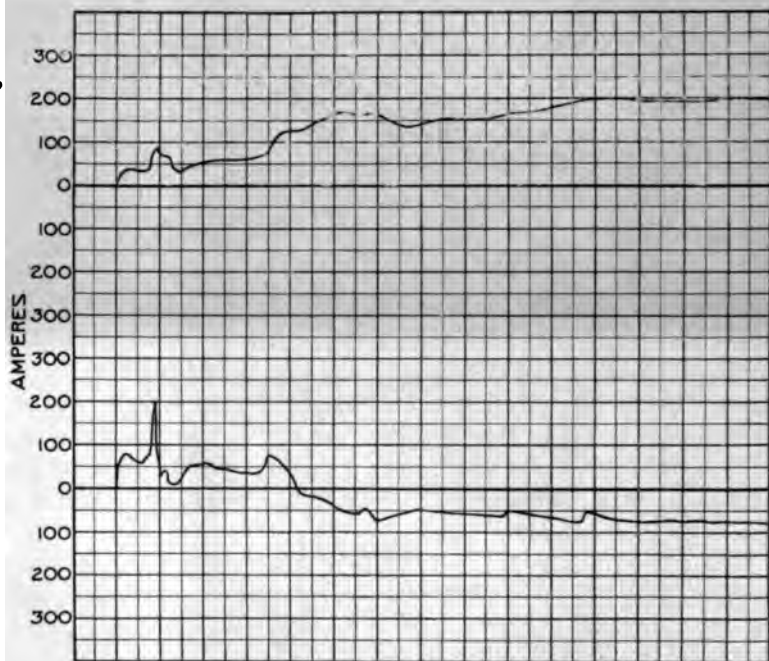


FIG.12

Fig. 12 represents two 25 h.p., 230 volt, series motors operating the bridge motion of a crane having a 116 ft. span. The controller is identical with that shown in Fig 5; in other words, there is one set of reversers, one acceleration resistor, one set of acceleration contactors, the fields are permanently in parallel, and the armatures are permanently in parallel. To our surprise, we found that the current in the top motor rose to 200 amperes, whereas the current in the bottom motor actually reversed and reached a value of 80

amperes. The bottom motor, therefore, was acting as a generator and was retarding the motion of the crane to the extent of 20 horsepower. In other words, one motor alone would drive this crane faster than the two motors in parallel. It was surmised that this condition was due to unequal currents flowing through the series fields and the instrument was connected to measure the currents in the series fields.

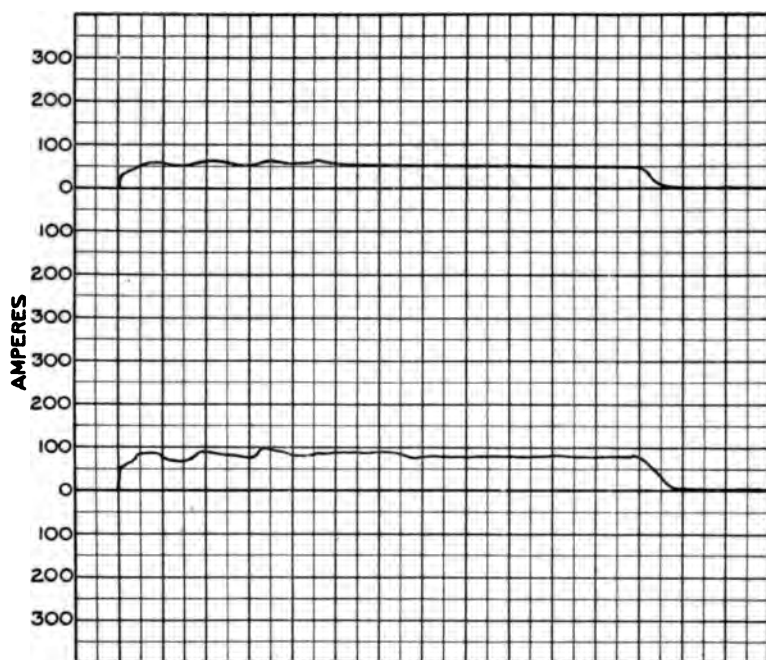


FIG.13

The results of this investigation are shown in Fig. 13, from which it can be seen that the series field current in the bottom motor is about 50% larger than that in the top motor. To correct this unbalancing, additional resistance was placed in series with the field taking the largest current, making the division of current as nearly equal as it was possible to do with the means at hand. Fig. 14 shows the motor currents after the fields had been equalized. One motor takes about 60 amperes running current and the other

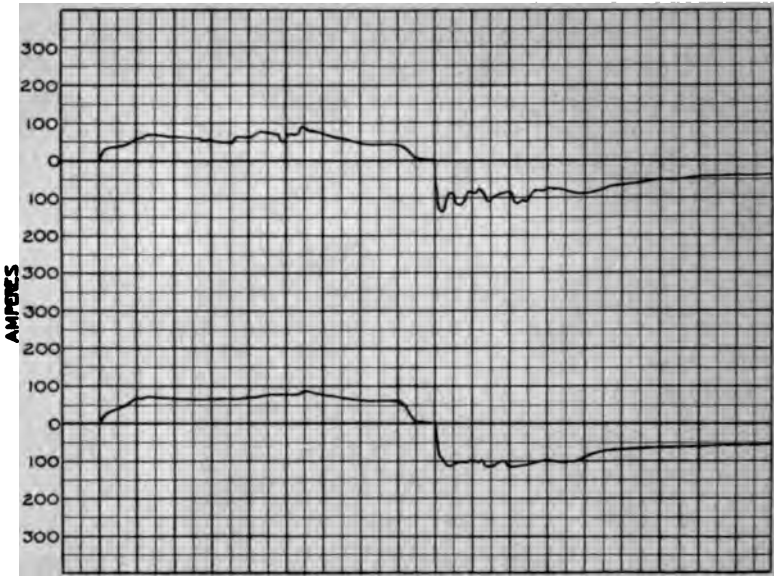


FIG.14

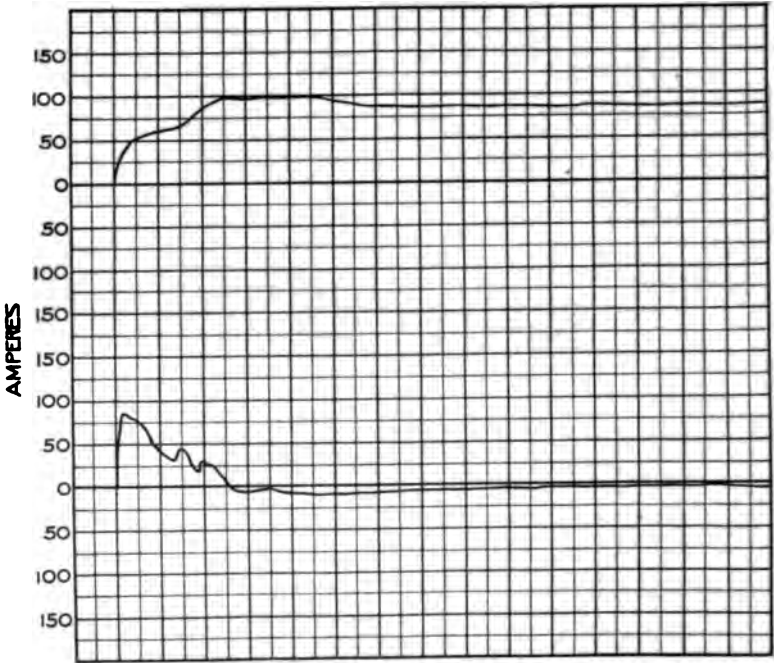


FIG.15

about 40 amperes, but by comparison with the conditions shown in Fig. 12, the installation could be regarded as fairly satisfactory. The current, at least, flows in the same direction in each motor.

Fig. 15 relates to two 20 h.p., 230 volt, series motors driving another machine. The controller was the same type that was used in the previous test. When acceleration was completed, the top motor took 90 amperes, whereas a small

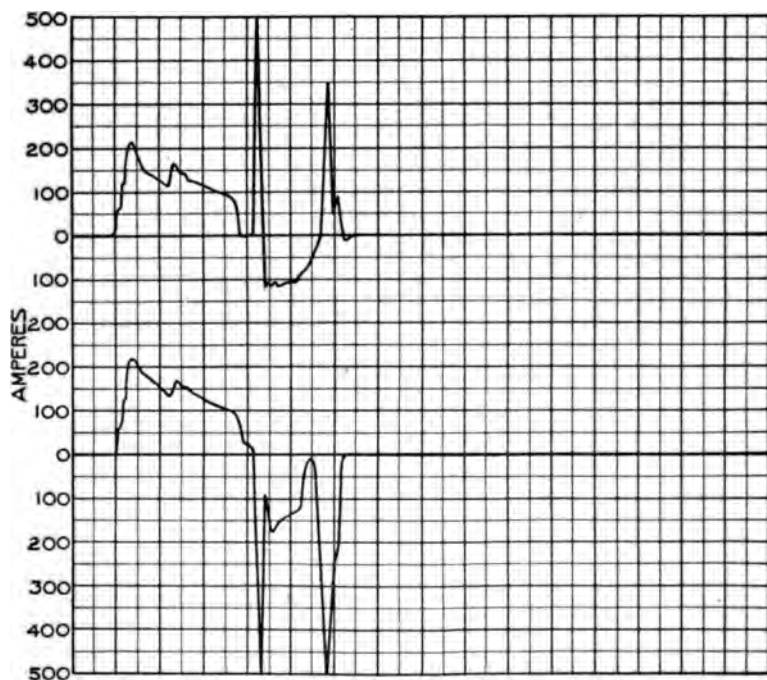


FIG.16

current of about 5 amperes passed through the bottom motor in the reverse direction. This particular machine has been running in this way for two or three years, and if anyone had remonstrated about this type of control, probably the answer would have been that inasmuch as it continued to run, it was all right. Within the last few months, however, the motors have given serious trouble, and it will soon be necessary to replace them. The point which I wish to emphasize, is that these two motors would have had

a liberal surplus of capacity had they been controlled in a correct manner. They were originally made larger than seemed strictly necessary in order to provide just this capacity for emergency, but due to the poor method of control, one of the motors was made to take so much current that there was no safety margin left. In other words, if one of two motors takes much the larger share of current, no doubt your conservatism in selecting motor sizes will enable

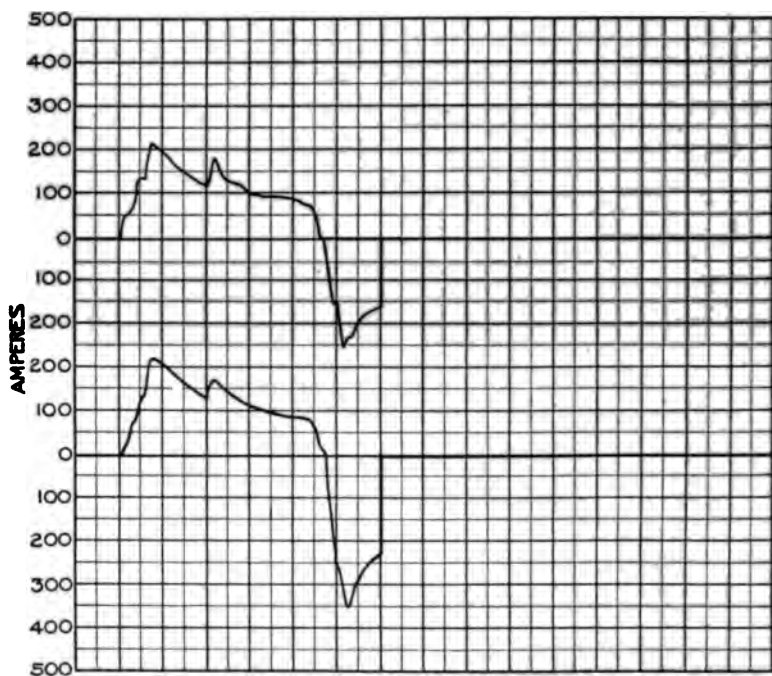


FIG.17

this equipment to operate for some time, but you have removed that emergency capacity which you intended to have and which would undoubtedly have resulted in longer life and fewer interruptions to service.

Fig. 16 relates to two 25 h.p. series motors regulated by a controller of the type shown in Fig. 6; in other words, there are individual reversers for each motor, one acceleration resistor, one set of acceleration contactors, and each series field is connected to its armature. I pointed out pre-

viously that this type of control is satisfactory for acceleration from standstill, but at the moment of reversal, heavy circulating currents come into existence. Fig. 16 is a striking confirmation of this theory. The acceleration is satisfactory, but at reversal, the bottom motor reverses the polarity of the top motor and a circulating current of at least 500 amperes flows through the two motors in series. There is a peculiar diminishing of this current shown on the curves

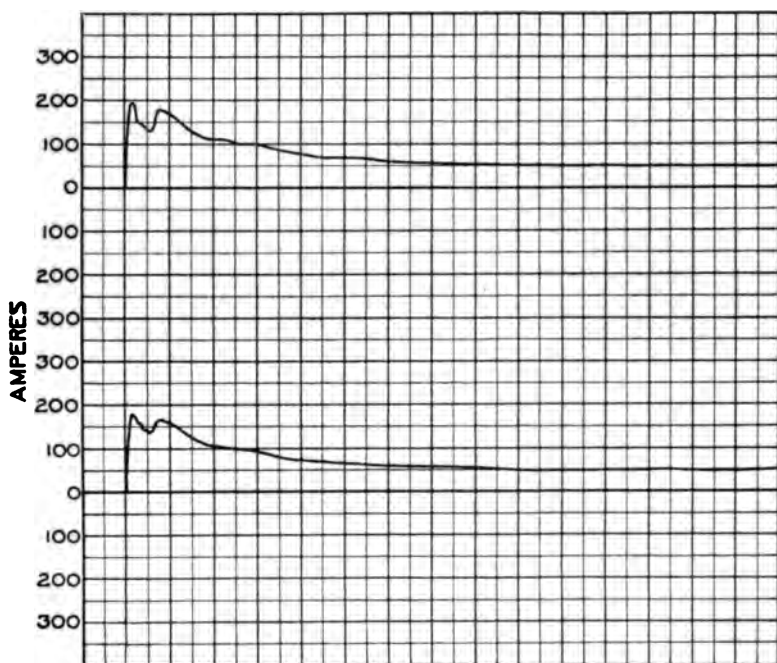


FIG.18

with a subsequent re-establishment of a somewhat smaller circulating current; I am unable to explain this, but it may be due to surges or it may be that the operator pulled the master switch to the "off" position and then threw it back again. This does not matter, however, the important point being the existence of the heavy circulating currents.

An attempt was made to correct this difficulty by connecting an equalizer from the junction of the series field and armature of the top motor to the junction of the series field

and armature of the bottom motor. This was merely a reversion to the type of controller shown in Fig. 5, with the fields permanently in parallel and the armatures permanently in parallel. The danger of circulating currents on reversal, was removed, but the division of load was not good, the results being indicated in Fig. 17.

Figures 18 and 19 show the operation of what I consider the correct method of control. The connections are

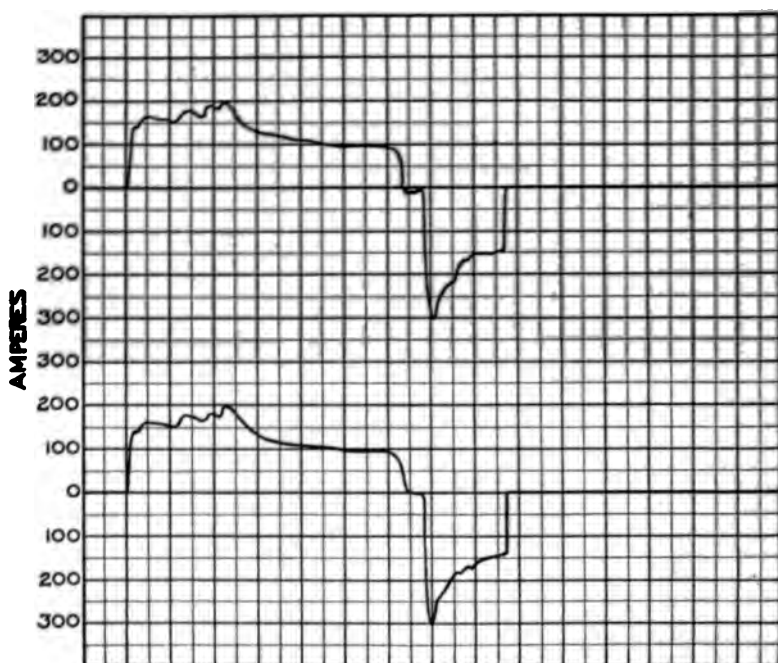


FIG.19

those of Fig. 9, which include for each motor, individual reversers, an acceleration resistor, and a set of acceleration contactors. The controller is made up of two-pole contactors throughout, one pole of each contactor being in one motor circuit and the other pole being in the other motor circuit. Fig. 18 shows the acceleration of two 30 h.p. series motors. Fig. 19 shows the acceleration and reversal of two 50 h.p. series motors. There is little comment to be made on these curves except to say that they are all right. The

currents during acceleration, reversal and during normal running are almost the same in each circuit; each motor is doing its fair share of the work, the only uneven division of load being due to imperfections in the motors themselves.

DISCUSSION

H. A. Lewis: Referring to Fig. 10, what will occur if you took the field of No. 2 motor and connect it with the armature of No. 1, or take the field of No. 1 motor and connect it to the armature of No. 2? Suppose you start out with No. 1 motor, go to the brake, then go from the brake to the retaining brake on No. 2 motor, from that to the field of No. 2 motor, and then to the line?

H. F. Stratton: You have your fields and armatures criss-crossed. I do not think that would make so much difference on the assumption proposed. I am assuming here that the current in each motor stops at the same time; that is, the current in the whole circuit would stop at the same time. But, perhaps the brake of one motor is applied more rapidly than the brake of the other motor, therefore the momentum is taken out of the armature of that motor much more rapidly than the other; the other is still endeavoring to rotate, and upon the analysis of the thing, I assume one was locked first. Now the line of that which I followed through that time, I do not think involved the question of current in the motor, it was merely that one motor was brought up more quickly than the other motor. I regard that not as an unbalancing of motor current, but of braking.

H. A. Lewis: Is it not a fact that the load would be equalized on those two motors?

H. F. Stratton: Not if one motor is brought more quickly to rest, by a more violent action of its armature brake than the other motor. I am assuming that the current is cut off entirely from each motor. Some rather preliminary investigation, which I have had made on that subject, seems to indicate that as being right, but it is not a question of one motor receiving current longer than the

other, or one brake longer than the other, but merely after the current has ceased entirely through the electrical system that one brake sets quicker than the other. One is considered stationary, while the other is endeavoring to rotate. I presume what you have in mind may be a little more to a uniform application of the brakes.

H. A. Lewis: On the ladle crane.

H. F. Stratton: Have you tried it out? I would be glad to have you tell me if you have.

H. A. Lewis: We have not gone into the matter far enough to say very much, but we are trying it out and it looks all right.

H. F. Stratton: I still think you will have the need of keeping the two brakes in fairly uniform adjustment.

H. A. Lewis: We find if the contactors fail to go in on one motor, the other motor attempts to start the entire load; if one motor is slow in starting, the same results are obtained.

H. F. Stratton: There are, however, disadvantages about criss-crossing fields. I realize it brings out those points that you mention, but I do not think you will get, perhaps, as accurate an acceleration as you would in connection with having each field directly attached to its own armature. It is a rather hard thing to analyze without a diagram before you in all its different phases.

George W. Richardson: We have tried two series shunt motors, both motors in parallel on table operating from same controller, and just as you say, when we tried to cross the fields and armature, we experienced difficulty. This wiring was made up from a diagram sent to us, but we found it would not work and immediately we had to make a change, and change over to the straight field and armature to the same motor. Of course, that was due a great deal to the position of the motors, that is, one motor was about 50 feet away from the controller, and the other motor about 200 feet away, and the difference in drop in the line would not allow it to work, but they are working all right now.

I will say that in this same mill, when we first put on the two parallel motors and first connected them together with a shaft, connecting both motors operating separate

tables, so that in case of one motor going down all we had to do was to take the bolts out of the couplings of the defective motor and then one motor would run both tables. We tried that for about one night. We actually twisted this connecting shaft off at one motor and it was a ragged break, so that we kept two motors in operation. We kept it on until morning, and then took the shaft out, and that is the way we are running today, without this connecting shaft. The back action, as you may call it, of those motors running in parallel, caused the strain sufficient to break a large shaft.

John C. Reed: The problem of parallel operation of motors on cranes is one which most of us have given more or less thought and has raised doubts in the minds of many as to whether or not it has any advantages over the single motor design.

It has been my practice to use a separate controller for each motor both when applied to the hoist and to the bridge. This, certainly, is a good practice, so far as the bridge is concerned, since the failure of either motor or controller will not put the crane out of service and this is one of the advantages of a double bridge drive.

There is some difficulty in automatically cutting out a motor on the hoist, since the series brakes must be taken care of. If the overload operates on one controller, disconnecting the motor and opening the circuit, the brakes connected in series with this motor will set and the other motor continue to operate, the result being that the bearing cap bolts will be stretched or the drum bearing caps broken.

A good plan is to connect the brakes of No. 1 motor in series with No. 2 motor and vice-versa, which will prevent the trouble with the bearing caps but has the disadvantage of putting the hoist out of service whenever there is a failure of either motor or controller and defeats one of the principal reasons for using two motors. It is entirely possible, of course, to provide knife switches on the trolley, arranged in such a manner that all the brakes can be placed in series with either motor or divided between the motors. This is the arrangement I am using and the only objection to it is the necessity of throwing these switches in case of failure of a motor or controller.

We had some trouble before cross-connecting the brakes but have not had any trouble since doing this. I do not think the difference in the torque of two similar motors, operating in parallel, will be sufficient to cause any mechanical trouble in the crane, since it is entirely possible to handle the loads with one motor cut out.

It is customary to figure the size of the motors so that either one can get away with the heat, although it may be somewhat overloaded.

To my mind, the proper way is to connect the brakes in the line so that the current to both motors will pass through all the brakes. The failure of any one motor will not disturb the operation of the other, and an open circuit will set all the brakes.

Brakes connected in this manner will probably require some modification in the design of the brake coils, since the current passing through the coils will be twice that when the brakes are connected in series with each individual motor.

The scheme of using a separate controller for each motor is especially advantageous in the operation of tilting furnaces and hot metal mixers which contain a large amount of molten metal. Let us consider first the tilting furnace for which I use four motors and four controllers—one for each motor. It is entirely possible for one of these to short-circuit and if it doesn't knock out the circuit breakers in the power-house, the furnace-man will never know it, since the overload will cut out this motor and the remaining three will continue to handle the furnace.

The practice in duplex tilting furnace operation is to pour out only part of the furnace contents. It is desirable to be able to tilt down the furnace rapidly so that the slag will not be poured off before the metal, and it is likewise important that the power be available to tilt it back in the same manner. We therefore do not care to take any chances on having a controller failure stopping the operation.

There is danger in case of a mixture containing, say, 800 or 1000 tons of metal and from which you wish to pour out only 20 tons, of not being able to get back the mixer after it has been tilted, due to controller failure. I therefore use two motors and four controllers, leaving a spare

set which can be cut in by the operator simply transferring his master switch handle to a spare master switch which controls the second set of solenoid controllers. I think it would be better to use four motors in the case of the mixer, but we have only two. I do not use any brakes on either the furnace or mixer motors, since they are balanced screw drives and brakes are not needed.

H. F. Stratton: There is another objection to that which I do not think very serious but propose mentioning. During the lowering by dynamic braking, most direct systems provide for the application automatically of the brakes. If you lose the motor circuit of one of the motors during the lowering, that would not lock the brakes under the scheme you suggest.

John C. Reed: I started out on the assumption that one motor would handle the entire load, so the failure of the dynamic brake in one motor I do not think would be serious.

H. F. Stratton: I am inclined to agree with you that that is the best place to put them.

John C. Reed: I might state in connection with holding speed on motor for a winch, that I have had a little experience along this line, and there are about three ways of doing it. One which has been suggested and the most usually employed is resistance in series with the motor to keep the motor from speeding. This is not in all cases satisfactory, and especially so in the larger machines. If you get up above 50 h.p. or thereabouts, it is better to place a resistance in parallel with the armature, which serves two purposes, the principal one being to strengthen the field of the motor, which will prevent the motor from running away and also give you the creeping speed desired. In handling heavy loads, another scheme is to use a compound motor, but this is a complication undesirable in the field. One other scheme I have employed satisfactorily is to use an a-c. motor—a-c. current frequently being the only source available.

H. F. Stratton: You think we get the torque through the motor sometimes before the brake is released?

John C. Reed: I have run up against that same thing and solved it by re-designing the brake.

R. B. Gearhart: There is one thing about this last statement that may influence Mr. Reed on the question he put forth. Even though you do have a well designed brake, and the operator is trying to throw the dynamic controller over into the highest speed point, it would take two brakes connected in the line having capacity for both motors in parallel. If one motor is cut out of operation probably you would not get enough current there to handle any brake at all. Does it not appear that way to you, Mr. Reed?

John C. Reed: I stated in my discussion that the problem involved was in the new design of brakes. As far as the manufacture is concerned, there is no question about that. Of course, usually when you run one motor, say on a crane, in place of two motors, the motor will be somewhat overloaded, and it is a question to my mind whether you won't have pretty nearly as much current flowing through the one motor as otherwise you would through the two. It is evident that the one motor is doing the work of two motors, and it is going to take as much current to do it; so I am not certain that you will have to change your brakes very much from the present design to get away with it.

F. W. Stevens: I would like to ask Mr. Stratton a question regarding the manually-operated dynamic brake controller; whether you have not had complaints from people before now in regard to brake lining being worn by operators advancing the controller from off to full on position in the lowering direction without giving the kick-off point the required time to release the brake, consequently running against same for the full drift wearing out the brake lining?

H. F. Stratton: Yes, we have.

F. W. Stevens: It has been a question in mind whether an interlocking device should not be devised to prevent such an occurrence; for instance, an electrical or mechanical interlocking device introduced at the kick-off point to prevent this occurrence.

H. F. Stratton: Our experience has been, if we put it on they take it off; they do not even keep the ratches on to keep the controller in the off-position. That is sad, but it is also true. Sometimes it is carried too far. I have known of fatal accidents due to removing the center ratch

from a controller so it can fall over one way or another. I know of a case that occurred not long ago. The master controller had that ratch taken off and it fell over slowly to the highest position. It crept up very slowly, and the man working beneath it or nobody else noticed it. It went up, broke the blocks, fell down and killed the man underneath.

F. W. Stevens: While most everybody is in favor of dynamic braking, this condition casts a reflection on dynamic installation.

H. F. Stratton: I do not like to see any change made. From the standpoint of safety, however, it is a very good thing to get the dynamic effort and the friction effort of the brake both working, and as I understand it you propose some scheme so the brake would not apply until the motor got to rest.

F. W. Stevens: When I spoke of a ratcheting device I did not necessarily mean such; it could be an electrical or mechanical device to overcome the negligence of operators and still operate the dynamic brake hoist as it is intended, thus showing its efficient qualities.

Leonard Work: I would like to ask Mr. Stratton in regard to a method of operating electrical hoists, of the type having only one direct-current motor. Where a hoist is operated by stevedores, as is quite often the case, they run them very often on the first or starting notches when the motor is pulling a heavy load, and so cause frequent burnouts of the resistance. A scheme to obviate this would be to do away with the starting resistance entirely and, by placing two motors on one shaft, operate them in series-parallel combinations as is done in street car service.

H. F. Stratton: I presume you refer to hoists for vessels loading at docks, don't you, Mr. Work?

Leonard Work: Yes, direct-current cargo-hoists.

H. F. Stratton: That is, the electrically-operated winches with the "nigger-heads" on them?

Leonard Work: That is the idea.

H. F. Stratton: They do not stop the motors in that case because they simply loosen up on the turns around the winch head when they want to pay out the rope. I have run into that question over at the Chelsea piers in New

York, which are possibly the best equipped piers in New York harbor. They tell me they had that trouble, and they solved it by putting part of a field on so the motors do not have a tendency to race, and the stevedores are willing to throw the controllers on to full-position and let the motors grind away. That is an interesting topic you mentioned, handling freight in and out of vessels. The way it is done you might as well have a steam engine or anything else. A compound motor would take care of it, would it not, in your case?

Leonard Work: It is not a question of very high speed, it is a question of very low speed. There is no trouble with the motors on account of high speeds as our motors do have a light shunt winding, in addition to the series winding, to prevent racing at light loads.

H. F. Stratton: Perhaps it is different. I have noticed them in New York harbor. They seem to be able to get quite a low speed and to maintain it even if the motor is running free. I was looking on yesterday for three or four hours when they were loading the "Celtic." I looked at perhaps six electric winches with the controllers in "full on" position, with all of them going all the time. They did not have much difficulty in getting low speed by letting the line slip, but the electric man over there told me they used to have trouble. I do not know very much about that question, except in the position of an interested outsider.

W. W. Geiser: I take it Mr. Work wants low speed running on the first notch. I had the same experience and got around it by putting heavier resistance in and lengthening it out. It did not take much extra space. You can then run on the first notch as long as you please.

H. F. Stratton: I believe the running friction is not very heavy; when the winch is running light it runs very free.

Leonard Work: An electric dock hoist, or winch, to be successfully operated by stevedores must be fool-proof and must require no more intelligence than necessary with the throttle of a steam hoist which may be operated in any position between "open" and "closed." When it is desired to hoist a heavy load very slowly the operator moves the controller handle to the position where a suitable speed is

obtained. This will be one of the resistance notches. It is also a peculiar habit of stevedore operators, when they want to hold a load suspended, instead of shutting off the motor and letting the latter's brake hold the load, to run the motor slowly while the man at the winch head slackens the turns of rope around it just enough so that the load is neither raised nor lowered. This condition sometimes lasts for several minutes, the power being expended in overcoming the friction between the rope and the winch head. In such a case, when the load on the motor is just about its capacity, a resistance intended only for starting purposes will be overheated and possibly burn out, although the motor may not suffer in the least. If the resistance is made large enough for continuous running, then it becomes bulky and occupies too much space, which latter is limited on a portable hoist.

It might be better if the resistance were entirely done away with, and speed control obtained through series-parallel combinations. This would entail the employment of two motors, instead of one, operating a single pinion. It would seem that the extra cost of two half-size motors, instead of one unit, would be offset by the advantages gained in control and the elimination of resistances and the losses occasioned thereby.

George W. Richardson: I have quite a number of cases of two motors running in series. On the table motors, I also have two armatures in one frame. I find even in that design, we come across the same old trouble that Mr. Stratton has shown; perhaps an air space of one side of one armature is a little bit more than the other. I have one motor running on a planer that, in fact, gives me more trouble, I think, from that cause than any other motor of this kind that I have around the plant. It is due to the magnet frame being turned a little bit out of center; it is not exactly true, as the other one is; when the armatures are placed in this motor they differ 15 or 20 revolutions, which is a drag on one motor, and which causes us to have a little trouble. But I have something like 60 of these two-armature motors running at our plant, and I do not experience very much trouble from them. What I mean by

that is, the armatures have equal space with each other, or parallel, so we have very little trouble from that point.

We find some of these motors give some trouble especially on quick reversing. The magnet frame of these motors are made in halves with the pole-pieces cast in them and some pole-pieces are a little larger or smaller than the others. In other words, they are rough castings, and, of course, it is a pretty hard matter to get equal square inches in all field cores, and when we place on field coils of the same turns, this may make a change, so that it may affect the lines of force somewhat. These are two-armature motors and not two separate motors. With the separate motors, as Mr. Stratton spoke of tonight, you will have the same trouble in manufacturing. I would say we run all our double-armature motors in straight series (except a few shunt-connected motors we use on planers.) We very seldom run them in parallel. We have experimented with them in series, parallel, and series-parallel, but we prefer operating them in series, as we have not had occasions of getting too high speeds, as these motors are mostly direct-connected. When we put the two motors on for heavy duty work, we place on the same size motors. In other words, if we have a 20 h.p. motor and find the most trouble is due at the moment of starting, then we put on another motor to save us from having trouble.

I have a case just now at our plant where we made a special 25-ton crane 10 feet wide and very heavy. Some of the boys call it the "gunboat." We have one motor on the traveling motion and a number of tests have proven that the motor is large enough to run this crane while it is in motion, but not for starting, and this motor gives a great deal of trouble from the starting effect. I know if we put another motor of the same size on this crane, we are liable to run for years without any trouble whatever on this traveling motion. I have two motors on some cranes, traveling motion, that have been running for the past 10 or 12 years in series and have had no trouble with them. I have also a lot of other cranes that run very good, having only single motors. But in all cases where I have two motors on the travelling of motion cranes, they run for a long while without the least bit of trouble, and I claim by putting two

motors on for heavy duty work, and operating them in series, we get two torques at the moment of starting and do not get high peaks, also slow start, and it will relieve us of the troubles, and it will save more than the cost of the extra motor by putting them on that way.

H. F. Stratton: I think that is a very interesting thing; it has always been interesting. The operation of motors in series, I find considerable merit in it, and I wish to amplify a thing I said a little while ago, that apparently, there was a disposition to slow down motors by putting motors in series. I think that the disposition can be eliminated by studying the ratio of gearing between the motor and the machine. I believe with two motors in series, you have a good deal of opportunity, to get as fast operation as with the two motors in parallel. It is not horsepower, speed or anything else, it is torque development in the motors and relative moment of inertia of the armature itself, and the equivalent moment of inertia of the entire mechanism which you have to move. That is the whole subject in itself, but I think it is worthy of more careful thought and extensive trials than you have made in the past.

Baxter Reynolds: I would like to ask Mr. Richardson if he puts the two motors on at the same time, or one at a time?

George W. Richardson: We do not take one motor out, but keep both motors operating at the same time. We do not have a great distance to run on our crane runways, and in series operating the motors give us the speed required for our conditions. If we have a long crane runway, it would be possible to put in a series-parallel control and operate the motors by series-parallel providing they were not on the same shaft.

On the subject of motors in series, there are two or three good points, I should think, especially if you have 250-volt circuits, you have half that on your armature. Dirt in steel foundries and steel mills is most injurious to deal with. Oil and dirt; and the higher the electro-motive force, the easier it is to carry over that oil and dirt and cause trouble; also, having two motors in series, we get two starting torques with the same current and start the load much easier than if only one motor is used.

I do not believe in putting two motors in series for every machine, but I think if I had my way, and was to design a rolling mill, I certainly would put two motors in series on heavy duty, load starting and reversing motions, on hoist as well as travel. That is my opinion.

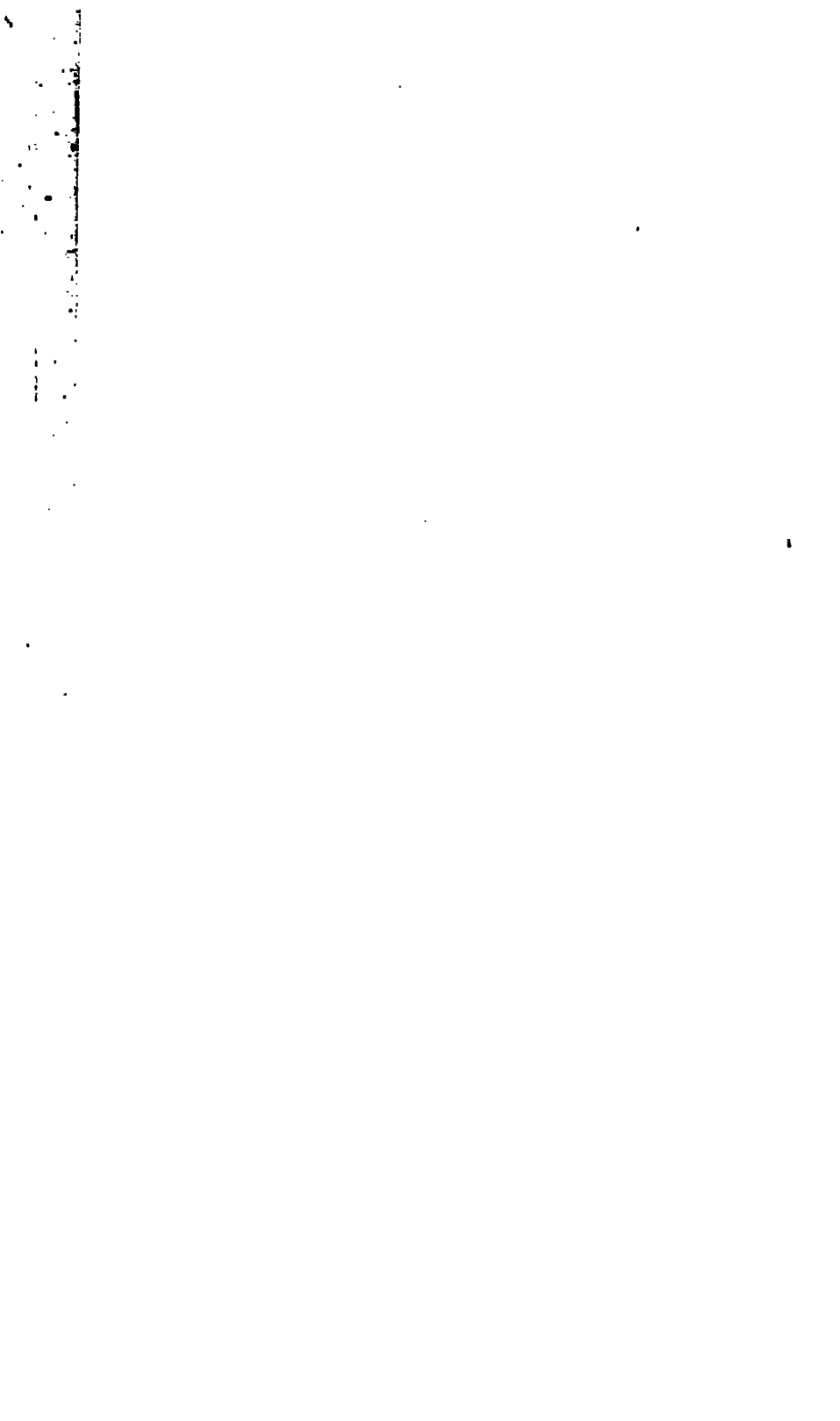
C. S. Lankton: I would like to ask Mr. Richardson (as I believe he has made the motors himself) whether the armatures were wound for normal voltage, or were they designed for the line voltage?

George W. Richardson: They were all designed for full line voltages. Prior to the designing of this double-armature motor, for 11 or 12 years, I used two motors in series on heavy duty work wherever I had a chance to use them and they always proved satisfactory. But our purchasing department objected to me buying two motors instead of one to do this class of work, so I had to do something if I wanted to carry out the same scheme, then I put two armatures in one frame. Some time after this, the question came up about equipping one of our old mills with electric-driven tables, etc. This was before the advent of the new mill-type motor now on the market. So I was asked about making the motors for this mill. I went down to Wharton Foundry, Philadelphia, and had them make for me a low carbon magnet frame and I made up a cast iron base and finished up one motor for trial and placed it in the place of a single-armature motor which was giving us considerable trouble. This double-armature motor worked so well on this trial that the firm decided to give me the job to make all the motors for this mill, lifting and transfer and hot bed tables. We made 60 motors and they are all working satisfactorily today.

We have experienced some trouble on these motors, such as Mr. Stratton has brought out in his talk. We snap off bolts and break caps occasionally. This is due somewhat to the design of motor base. I do not know how we are going to overcome it. Of course, as I say, this was the first design, and I never yet saw anybody design the first motor perfect. I do not say that my own design was perfect, especially the mechanical end of it. I would like to say also, we do not build these motors now, we buy them. The trouble of building a two-armature motor is, as I said,

in trying to get it accurately bored and also the same amount of iron in it so that the armatures revolve at the same speeds with the same field and voltages. To do that, we would have a hard job; therefore we have given up the idea of building any more of them except for very special cases.

I was asked the question the other day, by one of our managers, if I could make double-armature motors for some cranes that we have made and are waiting for motors to be installed. I said that I could not make them in time for their use. The motor companies are away behind in their deliveries, and we cannot get motors inside of 8 or 9 months after the receipt of orders, and we have these two cranes waiting for motors before we can put them in use.



SPEED CONTROL OF INDUCTION MOTORS FOR STEEL MILL DRIVE

BY J. D. WRIGHT

The ordinary induction motor with phase wound rotor is essentially a constant speed machine, but on account of its many desirable characteristics, such as its ability to exert very high starting and running torques and to carry heavy overloads, its high efficiency and its extreme simplicity of construction, considerable time has been devoted to the study of means of obtaining speed control.

Many methods have been used, among which are the following:

- Rheostat control
- Multispeed windings
- Concatenated control
- Scherbius system
- Kraemer system
- Heyland system

It is the object of this paper to describe a modification of the Scherbius system as applied to induction motors for steel mill main roll drives which permits the operation of the roll motor at speeds above and below synchronism.

An attempt is made here to present a clear view of the actions of the machines, avoiding all unnecessary discussion of the somewhat complex theories involved.

MAIN MOTOR

The main roll motor is, of course, the usual type of three-phase machine with phase wound rotor, the stator winding being the primary and the rotor winding the secondary.

It is well known that when voltage is applied to the primary windings, the alternating currents in the various coils produce a magnetic field which revolves at a speed depending directly upon the frequency and inversely upon the number of poles.

In the secondary windings, which are cut by the rotating magnetic field, there is generated a voltage which is a maximum when the rotor is at standstill. The secondary frequency is then exactly the same as the primary frequency.

The currents which flow in the secondary windings will exert a torque, causing the rotor to turn in the direction of the rotating field. The rotor speed will continue to increase,

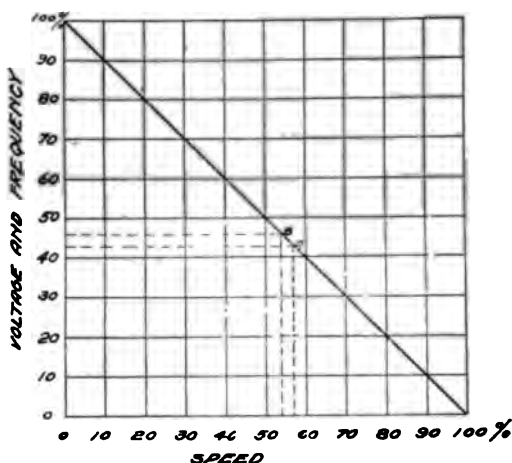


Fig. 1. Curve Showing Relation Between Secondary Voltage, Frequency and Speed of Phase Wound Induction Motor.

and at the same time the secondary voltage and frequency will decrease until the secondary voltage is just sufficient to send through the impedance of the winding sufficient current to develop the required torque. At exact synchronism the secondary voltage and frequency are zero. If the load remains constant (normal conditions being assumed) and the speed is reduced by the well-known method of inserting resistance in the secondary circuit, then at any other speed the voltage and frequency are practically proportional to the slip in per cent. of synchronous speed. These relations are shown by the curve in Fig. 1.

If, instead of the external resistance, a constant voltage at rotor frequency is used to oppose the secondary voltage, the speed of the rotor will adjust itself to such a value that the secondary voltage exceeds the opposing voltage by an amount equal to that necessary to send through the impedance of the circuits sufficient current to develop the required torque. If the opposing voltage is adjustable, the speed of the main motor may be changed simply by varying the opposing voltage.

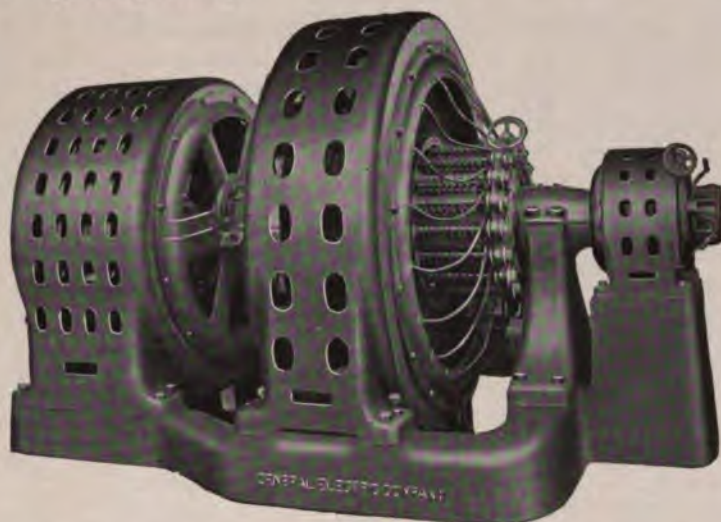


Fig. 2. Regulating Set Consisting of an Induction Generator, a Regulating Motor, and Exciter.

If the opposing voltage has a value represented by A in Fig. 1, the motor at no load will run at a corresponding speed. If a load should come on, the motor would slow down to B, for example, so that the increased secondary voltage would be just sufficient to cause enough current to flow to enable the motor to develop the required torque.

It is the function of the regulating set to provide a source of adjustable voltage which may be impressed on the secondary windings of the main motor.

REGULATING SET

Fig. 2 shows a typical regulating set. It consists of an induction generator, regulating motor, and exciter. The in-

duction generator is an ordinary squirrel-cage machine which may operate either below or above synchronism. When the speed is less than synchronism the machine acts as a motor taking power from the line. When the rotor is driven above synchronism the machine acts as an induction generator and delivers power to the line.

The regulating motor is a polyphase commutator motor with an armature similar to that of an ordinary direct-cur-

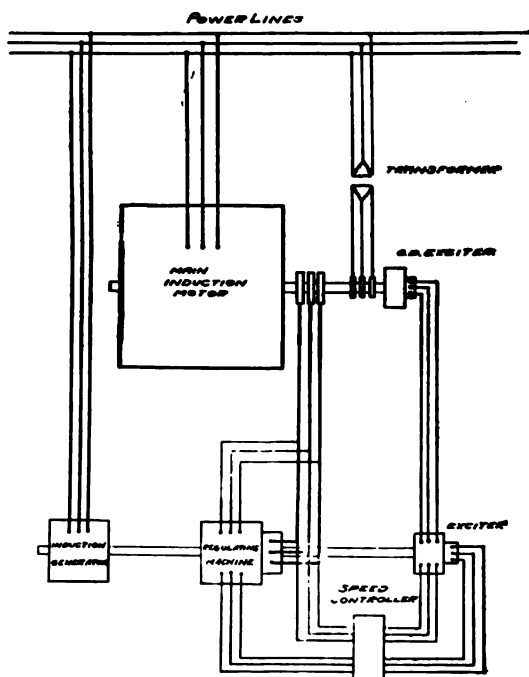


Fig. 3. Diagram of Connections for Induction Motor with Double Range Speed Regulating Equipment.

rent machine. Its stator is usually wound with three distinct windings; viz., a compensating field winding, an inter-pole field winding, and a main exciting field winding.

The exciter is similar to the regulating motor, but is somewhat simplified because of its smaller size and lighter service.

OHMIC DROP EXCITER

In addition to the regulating set there is required a

small auxiliary exciter which has been called an ohmic drop exciter.

The armature is mounted on the shaft of the main motor, so that its speed is always the same as that of the main motor. This exciter has the property of giving a constant voltage with a varying frequency; the frequency always being exactly the same as that of the secondary circuit of the main motor. This necessitates that the machine be wound with the same number of poles as the main motor.

The machine consists of an armature like that of a rotary converter, having both commutator and slip rings. The field punchings which surround the armature are without slots or windings. Since it is usually designed to handle three-phase current, its commutator is usually supplied with a multiple of three sets of brushes.

As shown in the diagram of connections, Fig. 3, the slip rings are connected through a transformer to the main power lines. If voltage is applied to the slip rings with the armature at rest the alternating currents in the various coils produce a magnetic field which revolves around the rotor at a speed depending directly upon the frequency and inversely upon the number of poles, the same as in an ordinary induction motor.

If the armature of the main motor be rotated at synchronous speed, and if the phase rotation of the ohmic drop exciter be such that the direction of rotation of its magnetic field is opposite to the mechanical rotation, the magnetic field would no longer rotate but would stand still in space. The armature conductors revolving at synchronous speed would thus cut this stationary flux and a voltage would be generated which would deliver direct current from the brushes on the commutator just as in a direct-current generator. At one half synchronous speed, for example, the magnetic field would be rotating at half speed and the armature at half speed, with the result that the armature conductors would still cut the flux at the same rate, and the voltage generated would therefore be the same as at synchronous speed and at standstill. The frequency, instead of being zero as at synchronous speed, would be one half of the normal frequency applied to the slip rings of the ohmic drop exciter, or exactly the same as the frequency of the

secondary of the main motor, since, as stated above, the magnetic field of the ohmic drop exciter is rotating in space at one half of its synchronous speed. At any other speed the voltage generated is constant and the machine delivers from its brushes alternating-current at a frequency equal to the slip frequency of the main motor. It may be noted that alternating current at zero frequency is direct current.

If the armature is driven above synchronism the magnetic field will of course rotate in an opposite direction and the machine will deliver from the brushes alternating current having a phase rotation reversed from that when operating below synchronism.

The use of this form of exciter has made possible the development of a method of operation of the main motor that retains all the desirable characteristics of the normal induction motor operating with short circuited slip rings, not only at speeds considerably below synchronism but equally well at speeds near synchronism, in synchronism, or above synchronism.

OPERATION OF THE SYSTEM

In the regulating motor the exciting winding is a shunt winding connected directly across the main induction motor slip rings. The shunt field therefore has practically a fixed flux regardless of variation in load on the main motor; for as the speed of the main motor varies due to a changing load the secondary voltage and frequency also vary proportionally, and therefore the flux remains constant.

The exciter armature is connected in series with the exciting winding of the regulating motor so that it can buck or boost the slip-ring voltage and leave any desired percentage to be applied to the field of the regulating motor. If it is desired, for example, to operate at a speed where one half of the slip-ring voltage is applied to the regulating motor field the exciter must buck away the other half. It must therefore have the property of generating a voltage always proportional to the slip-ring voltage, instead of a constant voltage like the regulating motor. Since it is an unsaturated shunt machine its voltage is proportional to its

field current. One of the fields is excited from the main motor slip rings over a resistance that is large compared to the reactance of the circuit, so that the field current is practically proportional to the slip-ring voltage.

Thus, since for any particular adjustment of the field resistance of the exciter the exciter terminal voltage is proportional to the slip-ring voltage, the difference between the two is, of course, proportional to the slip-ring voltage, and is therefore of the right nature to apply to the field of the

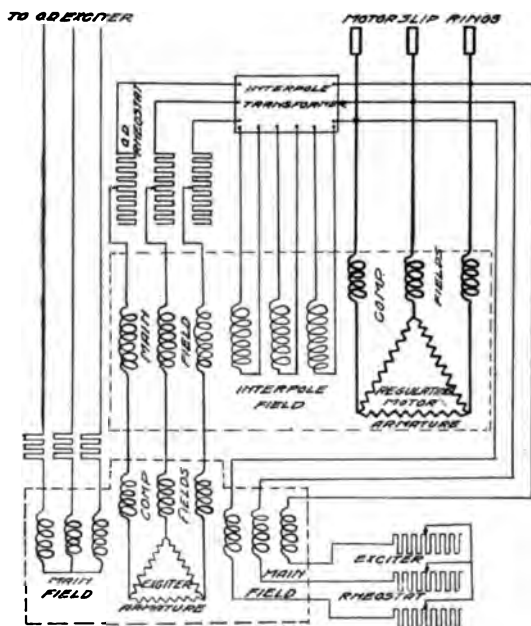


Fig. 4. Connections of Double Range Speed Regulating Equipment.

regulating motor to produce constant flux. A change in the exciter field resistance makes the exciter consume a different proportion of the slip-ring voltage, thus altering the regulating motor field and voltage and as a consequence the speed of the main motor.

Reference to Fig. 4 will show that the exciter has, in addition to the field excited from the slip rings, another field which is excited from the brushes of the ohmic drop exciter. It might be mentioned here that this exciter is called an

ohmic drop exciter because it excites the regulating motor exciter in such a manner as to cause the latter to generate a voltage which actually balances the ohmic drop in the field circuit of the regulating motor. The effect of this second field upon the speed variation compared to that of the first is small when operating remote from synchronism, but large when operating near synchronism. When operating

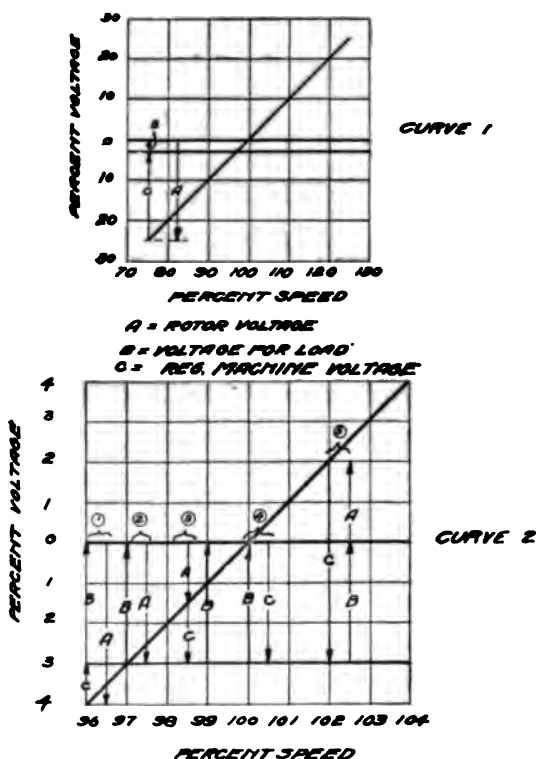


Fig. 5. Curves of Speed vs. Secondary Voltage Through Synchronism Resolved into Their Component Voltages.

exactly at synchronism it must of course provide all the required excitation.

To illustrate the actions of the different machines, let it be assumed that the main motor is running below synchronism and that it is desired that the speed be raised above synchronism. Fig. 5 may help to illustrate the various points. Curve 1 shows the variations of speed and

secondary voltage. It is assumed that the load is such that a voltage represented by B is necessary to send through the impedance of the secondary circuits sufficient current to enable the motor to develop the required torque. At any speed below synchronism the slip-ring or rotor voltage A must be greater than C, which is the opposing voltage, by an amount equal to B. Thus A, in addition to overcoming the opposing voltage C, also supplies the voltage B.

Curve 2 is an enlarged view of the same quantities close to synchronism. Condition 1, Curve 2, has been reached by decreasing the voltage of the regulating motor. This regulation toward synchronism was accomplished by increasing the resistance in the ohmic drop rheostat and decreasing the resistance in the exciter field rheostat. (When regulating toward synchronism the resistance in the exciter field rheostat is decreased in order that the exciter may be made to consume a greater and greater percentage of the slip-ring voltage, as the voltage consumed in the field windings of the regulating motor decreases when the flux and frequency decrease in approaching synchronism.) Condition 2, Curve 2, Fig. 5, is where the regulating set offers no opposing voltage and the voltage A, is equal to B. At this point the conditions are practically the same as when operating the main motor with the slip rings short-circuited. The circuits to the main fields of the regulating motor are completely opened so that no voltage is generated.

Up to this point it is evident that, since the rotor voltage exceeds the voltage of the regulating set, the regulating machine has been acting as a motor and the induction generator, being driven above synchronism, has been delivering power to the line. It should be noted that the regulating motor has the characteristics of a shunt wound direct-current motor. That is, its speed with a given field is proportional to the voltage applied to the armature. When operating the main motor below synchronism it is evident that the induction generator must be driven above synchronism in order that the power delivered to the regulating motor may be absorbed. It is also evident that if the regulating motor were connected to main motor slip rings without the induction generator the speed of the main mo-

tor would continually decrease and the speed of the regulating motor increase; because, since there would be no torque to resist the torque of the regulating motor, the latter would speed up. Its voltage, opposing the rotor voltage, would therefore increase, with the result that the secondary voltage of the main motor would no longer be sufficient to send through the impedance of the circuits sufficient current to enable the motor to develop the torque by the load, and the main motor speed would decrease. The rotor voltage would then become higher, causing the speed of the regulating motor to still further increase. This action would tend to continue as long as the rotor voltage could continue to increase.

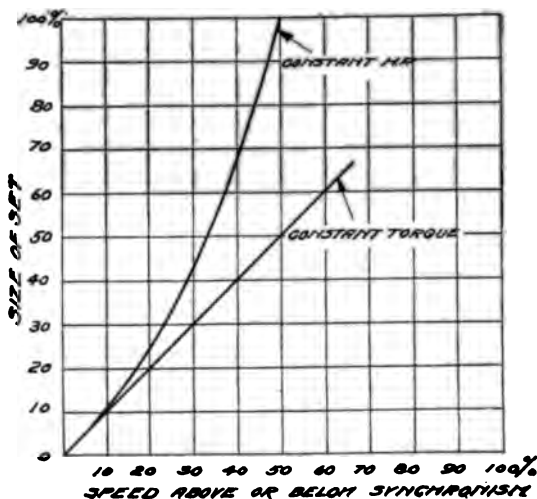


Fig. 6. Curve Showing Size of Regulating Set in Per Cent. of Capacity of Main Motor.

Referring further to Curve 2, it is seen that, in order to regulate toward synchronism from condition 2, it is necessary that the voltage of the regulating machine be reversed. To arrive at condition 3, the regulating machine must act as a generator and assist the rotor voltage A by a voltage equal to C to supply B . At exact synchronism, condition 4, the rotor voltage is zero and the voltage of the regulating machine must be large enough to send through the secondary circuits sufficient current to enable the motor

to develop torque required by the load. If voltage C is still further increased the main motor torque increases above that required by the load, with the result that the rotor speed must increase. The rotor voltage therefore begins to develop in the reversed direction, so that at condition 5 the voltage C of the regulating machine must be equal to A plus B.

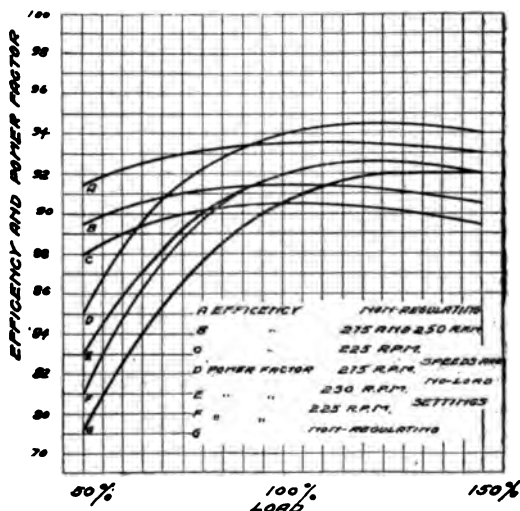


Fig. 7. Efficiency and Power-factor Curves for 12-pole 2200-2000-1800-h.p. 275-250-225-r.p.m. Motor with Regulating Set.

SIZE OF REGULATING SET

The size of the regulating equipment is determined by the amount of speed adjustment required above and below synchronism. The secondard energy from the main motor is equal to the following:

$$\frac{\text{Slip}}{1 - \text{Slip}} \times \text{shaft horse power}$$

Figure 6 shows the size of the regulating equipment for any speed adjustment above or below synchronism where the main motor is called upon to deliver either constant torque or constant horsepower. From an inspection of this curve it is evident that it is desirable to have the synchronous speed of the main motor midway between the maximum

and minimum speed at which it is required to operate, as under this condition the size of the regulating equipment is a minimum.

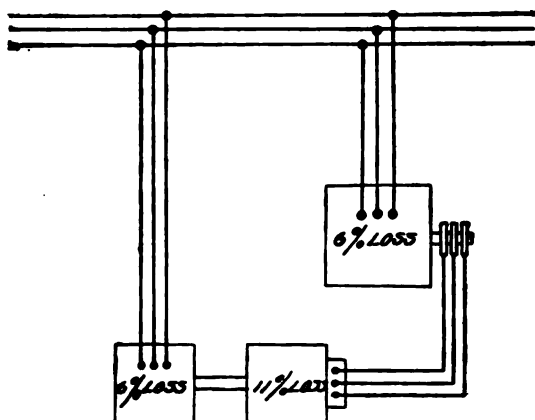


Fig. 8. Main Motor 1600-2000-2400-h.p. 20 Per Cent. Regulation Above and Below Synchronism.

Size of Regulating Set	400 h.p.
Losses Main Motor	120 h.p.
Losses Main Regulating Motor	44 h.p.
Losses Induction Motor generator	24 h.p.

Total Loss 188 h.p.

Shaft H.P. at Max. Speed 2400
2400

$$\text{Efficiency} = \frac{2400}{2400 + 188} = 92.5 \text{ per cent.}$$

Shaft H.P. at Min. Speed 1600
1600

$$\text{Efficiency} = \frac{1600}{1600 + 188} = 89.5 \text{ per cent.}$$

Shaft H.P. at Average Speed 2000.
2000

$$\text{Efficiency} = \frac{2000}{2000 + 120 + \text{Approx. } 2.3 \times 68} = 92.5 \text{ per cent.}$$

EFFICIENCY AND POWER FACTOR

Fig. 7 shows typical overall efficiency and power factor curves for an induction motor with regulating equipment. The illustration also shows the efficiency and power-factor curves for the main motor when operating without the regulating set, that is, with short circuited slip rings. The efficiency values under this condition are of course higher because of there being no regulating set losses. The pow-

er-factor values are lower because the power-factor correction obtained from the regulating set is no longer available. Fig 8 shows a diagrammatic arrangement of connections with approximate distribution of losses and calculations of overall efficiency for various assumed conditions. The speed of the main motor is assumed to be regulated from 20 per cent. below synchronism to 20 per cent. above synchronism with constant load torque. The power transmitted by the regulating set, which is determined by the percentage regulation below or above synchronism, is approximately equal to,

$$\begin{array}{l} \text{Slip} \qquad \qquad \qquad 20 \\ \hline 1-\text{Slip} \qquad \times \text{shaft horsepower or} \quad \frac{\quad}{80} \times 1600 = 400 \\ \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad 20 \\ \text{horse power, or, above synchronism,} \quad \frac{\quad}{120} \times 2400 = 400 \text{ horse-} \\ \text{power.} \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad 120 \end{array}$$

When operating at the intermediate speed it has been assumed that the losses in the set would be approximately 2-3 of the losses at maximum or minimum speed, as the set is then not handling as much power as at other speeds.

CONTROL

Magnetic control is usually provided for induction motors with speed regulating sets, and is especially desirable on account of the ease with which the proper interlocking of the various circuits may be accomplished.

The control is so designed that the following sequence of operations must be observed when starting the main motor from rest, assuming that it is desired to operate with the regulating set:

1. The master controller which governs the operation of the contactors controlling the main motor must be in the off position.
2. The speed regulating rheostat must be placed in the starting position. (The position corresponds to the setting at which the regulating machine generates no voltage.)
3. The regulating set must be started from an ordin-

ary starting compensator by the squirrel cage machine acting as a motor.

4. The main motor may then be started by the operation of the master controller.

A contactor is provided for opening the armature of the regulating motor and another for opening its field circuit when the main motor is being started from rest. Provision is made for closing these contactors after the motor has been accelerated and all the starting resistance cut out of the secondary circuit.

It is evident that to prevent an excessive flow of current the regulating set must be connected to the main motor slip rings at a motor speed corresponding approximately to the setting of the speed regulating rheostat. This has been chosen as the normal speed of the motor without the regulating set.

Provision is, of course, made for operation of the main motor without the regulating set, and a double throw control switch is arranged to make the proper change in connections.

In case it is desired to "plug" the main motor to stop it quickly, additional secondary resistance is provided to limit the current.

The regulating set is automatically disconnected from the main motor when the master controller is thrown to the reverse position.

ADVANTAGES OF DOUBLE RANGE REGULATION

Double range speed regulating equipments (that is, those that permit operation of the main motor above and below synchronism) evidently possess several important advantages from an operating point of view. The following may be noted:

Flexibility: The double range system permits the operation of the main motor non-regulating at an average speed with maximum efficiency. (With single range systems providing speed reduction only, the main motor, without the regulating equipment, operates at maximum speed.)

Maintenance: The double range auxiliary set may be idle while rolling at the non-regulating speed, thus minimizing wear and upkeep.

Production: In event of trouble with the regulating set, the main motor operating at an average speed will permit rolling a wider variety of sections than will a single range system operating under similar conditions. Sections for which higher speeds are desirable can nearly always be rolled in emergency at the average speed with reduced tonnage, while if trouble develops with a single range set, many low speed sections cannot be rolled at synchronous speed.

Running Points: A great number of running points up to 100 or more can easily be obtained.

Power-factor: Improvement of the power-factor of the main motor is easily obtained.

Asynchronous Apparatus: Since no synchronous machines are used there is no tendency for the regulating equipment to fall out of step under sudden loads.

DISCUSSION

G. E. Stoltz: Mr. Wright's paper is most welcome and appropriate before an Association of this kind, particularly in view of the fact that the equipment which is described is comparatively new and the demand for adjustable-speed motors on rolling mills is increasing. The advantages are better understood now as the equipments which are in operation have shown that the extra expenditure is justified by the increased production and the greater scope of material which can be obtained from one mill.

Ordinarily the a-c. adjustable-speed equipments are installed on mills rolling a diversity of products where it is necessary to operate at a slow speed for the large finished material, and in order to obtain the maximum output the mill must be speeded up when rolling small sections. The equipment may operate at some particular speed several hours, or for a day or two before any change is made. This applies particularly to something of the merchant or bar mill type, however, on rod mills which are generally driven by a separate motor on each train it is necessary to adjust the speed of the motors while rolling in order to maintain approximately the same length loop between trains.

An equipment which is not sensitive to quick changes of speed is required on this type of application.

A still different requirement is being met by the installation of the drive on the 3-high structural mill at the Inland Steel Company. It consists of a d-c. motor which obtains its power from a fly-wheel M-G. set. The apparatus is practically a reversing equipment and can be used as such, but normally the motor runs in one direction. This mill will roll structural shapes and it is intended to enter the metal at a comparatively slow speed and then immediately speed up, reducing the time to make the long passes. This type of drive will respond to speed changes much more rapidly than the a-c. adjustable-speed equipments; and enables them to obtain a greater tonnage than would be possible if the mills were run at constant speed or by an adjustable a-c. motor equipment. Objection often is made to the increased cost of an adjustable-speed equipment. but in many cases the added flexibility of the mill permits such an increase of production that the first cost of the equipment is of little importance.

Among some of the first installations made where the mill required more than one speed, Cascade motors or multiple-speed motors were installed. These equipments are limited to few speeds which in most cases were adequate. Their main limitation is due to the fact that practically each equipment required special design, which seldom could be duplicated in other installations. The present systems as offered by the manufacturers permits the use of a combination of apparatus which can be standardized.

Each of the various schemes can either be applied giving constant torque or constant horsepower. This question should always be given consideration as each scheme has its best field. In a great many cases the mill will roll large material at the lower speeds, and smaller sizes at higher speeds. When rolling the large cross-sections it is customary to take heavier drafts which naturally require increased torques. This type of application, of course, would be favorable for a constant horsepower output. On other mills the same size billets are used in the roughing stand, the finishing train simply making fewer passes to obtain a product of larger cross-section. Such a mill would not re-

quire increased torque at the slow speed. Quite a number of the adjustable-speed mills are provided with fly-wheels to equalize the intermittent load. The fly-wheel effect varies inversely as the square of the speed so that the motor is not so well protected by the fly-wheel at slower speeds, and is required to take higher peak loads. This condition can better be met by installing a constant horsepower equipment.

The operating performance of the several schemes is practically the same, as the power factor of the main motor can be corrected in all of the systems offered. The overall efficiency of the constant horsepower method of drive is usually better than that of the constant torque scheme as all of the energy of the former is utilized as mechanical power with the exception of the small losses in each machine. The constant torque system requires that a certain amount of energy be circulated through the equipment which is not utilized as mechanical power. This might be compared to the losses incurred by wattless KVA in an a-c. machine. If the equipment is to operate 25% below synchronous-speed, 75% of the input to the main motor will be given up to the mill as mechanical power, the other 25% (losses neglected) will be circulated through the auxiliary equipment and returned to the main power circuit. If a constant horsepower scheme were used the main motor would only be required to take 75% of the energy required by the constant torque scheme as all of its energy is utilized as mechanical power, the circulation of the slip energy being avoided.

The Westinghouse Company has not advocated any one system, but has found that the individual application may require any one of several schemes, each having its own characteristics which may or may not prove to be advantageous, depending upon the particular application. Ordinarily the Ilgner system is too expensive, but the ease with which it responds to rapid changes of speed warrants its use on a mill similar to the structural mill for the Inland Steel Co. A two-speed motor has rather narrow limitations, but if a previous design can be used or a two-to-one speed motor utilized a very attractive proposition can be offered. Often a wide speed range is desired which would justify the use

of direct-current motors for the main drives with rotary converter or motor-generator sets to transform the alternating-current to direct-current.

For moderate speed ranges we have to offer either the rotary converter, or the frequency changer scheme of speed adjustment. The rotary converter scheme employs apparatus which has had years of development, is absolutely stable under the varying load conditions met with in steel-mill practice, is efficient, and insures continuity of service as each machine is so common that both the rotary and d-c. motor or motor-generator set are thoroughly understood by the mill operators. Hand control can be used or a master switch placed in the mill so that one of the mill men has full control of the equipment.

As far as operation is concerned it can be used equally as well on a 60 or 25-cycle application. Assume that it is desired to operate a 60-cycle motor 30% from synchronous, 30% of 60 cycles is 18 cycles, which would be the frequency of the secondary circuit of the main motor. A standard 25-cycle rotary is easily adapted to such an equipment. If the same reduction is desired on a 25-cycle application, the secondary frequency will be 7.5 cycles. Again a 25-cycle rotary is selected which would be operated at 7.5 cycles or at 30% of its normal speed which naturally reduces its capacity. This makes it necessary to select a comparatively heavy machine.

The frequency changer scheme utilizes a frequency converter which returns energy to the power circuits by means of transformers. The appearance and construction of the frequency converter resembles that of a rotary converter in that the rotor carries the commutator at one end, and slip rings at the opposite end. The commutator end is connected to the secondary circuit of the main motor, and the slip ring end to the step up transformers which return the slip energy to the power circuit. There is but one winding on the frequency converter that being the rotor winding which is similar to the rotary converter winding. The stationary part consists of a laminated steel ring with no winding. The only purpose of this iron is to carry the magnetization set up by the rotor.

The frequency converter develops no torque, and as there is but one winding there is no tendency to distort the field common to machines having more than one winding. Ordinarily the commutating apparatus requires very accurate brush setting, but on these machines the brushes are placed on the commutator with no particular reference to the stator, it only being necessary to have approximately the correct spacing between the brush-holders.

Since the frequency changer develops no torque, a driving motor is supplied which simply overcomes the bearing friction and windage of the converter. The character of the load on the mill does not modify the requirements of this machine.

The stationary transformer is one of the most reliable pieces of electrical apparatus built which adds little hazard to interruption of the mill. The losses in this auxiliary apparatus is unusually low as the efficiency of both the frequency converter and transformer is comparatively high. The average loss in a six-phase rotary converter winding is 26% of the same machine carrying the same current as a direct-current generator, while this armature used as a frequency changer has a loss of 18% of the direct-current machine. One hundred per cent. power factor can be obtained on the equipment without any noticeable change in its stability or commutation.

The equipment is as simple as can be imagined as few windings are involved, and in every case repair-work can be carried out with ease. The system requires no corrective apparatus such as commutating poles or neutralizing windings to make the apparatus operative. For this reason it is absolutely stable under the varying load conditions found in steel mill service, and is not sluggish in responding to adjustments made to obtain a variation in speed. Its operation can be controlled from the mill, and its reliability is such that a rolling mill man not familiar with electrical apparatus can operate it from some suitable point in the mill proper. Even the rotary converter with its field coils designed to carry a comparatively small current and the construction and arrangement such that the field can easily be removed in case of repairs, cannot claim simplicity of the frequency converter, the stationary of which is nothing

more than a bare ring of iron. As far as this part of the machine is concerned the chances of failure are practically nil.

F. B. Crosby: This subject of adjustable-speed control for large induction motors is one of great personal interest to me. The system which Mr. Wright has so clearly described this evening is the latest result of nearly seven years of continuous effort on the part of our designing engineers, plus the previously accumulated experience of the Brown-Boveri Co. in building and operating some thirty or more of these equipments before we began a systematic investigation of the relative merits of the several systems proposed for adjustable-speed control.

Realizing the need in the steel mill for a system of main roll speed control which would assure a wide range of operating speeds, each constant under varying load, we began seriously to investigate the possibilities of the most promising systems in 1910, namely the so called:

- 1st—Heyland Frequency Changer.
- 2nd—Kraemer Rotary Converter.
- 3rd—Scherbius Commutator Machine.

The first possibility was quickly discarded because of inherent objections, difficult if not impossible to overcome, such as complexity of control, instability, lack of flexibility and poor commutation characteristics due to the inevitable distortion of the alternating wave form.

The second system, while also presenting certain objections, such as instability of operation at low secondary frequencies near synchronism, and the usual objections associated with synchronous apparatus in steel mills, none the less appeared to be the best solution offered at the time, for sixty-cycle systems requiring a range of 30% or more speed regulation.

The first bona fide proposition involving dynamic speed adjustment of large induction motors made in this country so far as I can ascertain, I had the pleasure of preparing in the fall of 1912. This proposition involved the use of a rotary converter in the secondary circuit of the 6500-h.p., 107 r.p.m. 60" universal plate mill motor at Gary, and was arranged to give continuous speed control from 50 to 86

r.p.m., the operation under overloads at speeds nearer synchronism being doubtful.

Even in 1910 the operating characteristics of the third system using the Scherbius commutator machine appeared to be far the best for practically all 25-cycle motors and for 60-cycle motors requiring 25 to 30% speed regulation or less. We built an experimental machine in 1910-1911 very similar to the Scherbius machine but requiring the use of a six-phase secondary in the induction motor. The results obtained were so satisfactory that we finally acquired the Scherbius patents permitting the use of three-phase secondary winding in the main motor and complete compensation in the commutator machine. At the same time we acquired the services of Dr. Meyer Delius, formerly Dr. Scherbius' assistant, who as mentioned before, had already designed and put into operation about thirty of these sets, so that it is little wonder that the first as well as all succeeding sets built by the General Electric Co., have given successful operation from the start.

It is of interest to note, however, that for wide ranges of control on 60 cycle systems, we continued to recommend the so-called Kraemer system. The first system of this character designed for the service in this country was built by the General Electric Co. and installed by the Union Rolling Mills Co., of Cleveland. This drive included a constant torque induction motor, 1400-950 h.p. at 600-405 r.p.m., with a direct connected auxiliary d-c. motor 0-450 h.p., 600-405 r.p.m. and a 325-kw. rotary, thus permitting the operation as a unit at constant horsepower (1400 h.p.) throughout the speed range guaranteed.

We were now in a position to meet all practical adjustable-speed requirements; since, however, the speed torque characteristics of an induction motor are practically the same above and below synchronism, there appeared to be no reason why we could not operate the motor equally well above and below its synchronous speed, thereby reducing the capacity of the auxiliary devices for a given speed range, increasing the overall efficiency and incidentally obtaining a sufficient range of speeds with the commutator motor to meet all practical requirements of both 25 and 60 cycle sys-

tems, thus eliminating even the occasional necessity of using the rotary converter system.

The difficulty lay in a practical means of insuring stability of operation at and near synchronism. After several years of quiet but persistent effort, the means was found. Very satisfactory tests were obtained at the factory but before quoting prospective customers we wished to observe this system in operation under mill conditions. Permission was secured from the American Iron and Steel Co., which Company had had seven of our single-range sets in operation for upwards of two years—to try out the double range system by the temporary addition to their existing equipment of the ohmic drop exciter described by Mr. Wright. In company with Mr. Hull, our designing engineer, I had the pleasure of assisting at these tests. I shall never forget our elation when even with the makeshift testing apparatus at hand, we actually rolled steel with an induction motor running at and above its synchronous speed. The results were absolutely satisfactory in every respect. Nothing was left in doubt. Since that time we have quoted nothing but the double-range system and have sold to date 23 double-range equipments, aggregating 35,210 h.p. normal continuous rating, with 4,320 kv-a. auxiliary commutator machines.

The double-range system permits the operation of the mill at an intermediate speed with auxiliary equipment idle. If due consideration is given the relation of this intermediate speed to the chief product rolled, the set may be idle much of the time and wear and depreciation minimized.

All the usual characteristics of the mill-type induction motor are retained. The motor may be started, stopped, plugged at full-speed from the master controller with the usual current limit features. If fly-wheels are required, provision for automatic slip can be had when operating regulating just as when non-regulating.

Synchronous speed as a definite point disappears. With provision for 10% automatic retardation, if the no-load speed is adjusted for 5% above normal synchronous-speed, the speed will automatically drop to 5% below synchronism at full-load and return to 5% above as the load falls off.

Wilfred Sykes: I want to take the opportunity of congratulating Mr. Wright on the clear way he has presented

this subject to the Association. I think his paper is one that might be used as a model in the clear way he has presented a complex problem.

The whole subject of variable speed of induction motors is somewhat complex. Many schemes have been proposed. The use of the rotary converter is a fairly obvious way of obtaining results, and it is not at all new; but it was a good many years before it was thought the advantages to be obtained by regulating the speed of induction motors driving rolling mills would warrant the extra expense.

I believe the first installation in this country was put in at Canton. There it was hardly given a good chance; it was added to equipment not designed for such regulating arrangement, but it has been working very satisfactorily for a number of years. It is very interesting and instructive to see the Scherbius system, which originated in Europe, modified and the bad points eliminated in the scheme gotten up by the General Electric Company. There is still a field for a rotary converter scheme when used with an induction motor and d-c. motor on the same shaft. As a characteristic of such equipment is constant horsepower, there are many kinds of mills on which constant-horsepower equipment is more suitable than the constant-torque arrangements, and in order to take care of these mills with an arrangement with constant-torque, the main induction motor and regulating equipment must be made correspondingly larger.

In connection with installation for a mill with wide speed range, it is rather a special application, no regulating equipment, Scherbius, rotary converter, or any of these schemes would be satisfactory. The question of efficiency was not the controlling feature, as it was necessary to run the mill at low speed, possibly 50 to 60 revolutions to enter the first blank, where after the blank had been more or less reduced, it could enter at higher speed, and the mill speed will vary from 50 to 120 revolutions. That field could be met by any of the other regulating systems, and where extra losses in the equipment really did not matter. Of course, equipment is much more excessive than any regulating arrangement which has been described.

It is very interesting to hear from Mr. Crosby how the General Electric Company spent years in developing their equipment. It is also interesting to note the frequency changer is an old device. The original patent on this scheme dates back 15 years. It is hard to get any one scheme that will meet all conditions, and it is going to be a matter of development which will work out in the long run to be simple and most desirable. The frequency changer scheme has similar machines, and although the regulating transformer may not seem favorable, you don't necessarily use a transformer. As at Jones & Laughlin's where you maintain certain length of loop, it is quite possible to use induction regulator and obtain infinite number of speeds.

A. M. Dudley: Referring to Mr. Stoltz' discussion there is an interesting point of comparison between these two systems. To an induction motor man the novel feature of all these schemes is passing the motor through synchronism. This particular point is accomplished in both the schemes you have heard described tonight by the same special machine. I would call your attention to the fact that the machine which Mr. Wright calls an "ohmic drop exciter" and Mr. Stoltz calls a "frequency changer" are identical in their construction and function. And it is to this novel machine that both systems owe their success. Mr. Crosby has graphically described what is really an epoch in the art—the accomplishment of operating an induction motor above synchronism. We feel that the auxiliary machine which is capable of pulling the large machine through synchronism—because at the instant of synchronism it is a direct-current machine—is capable of securing the simplest operation over the entire range of speed, below and through and above synchronism. We are, therefore, proposing the system described by Mr. Stoltz where the greatest simplicity and flexibility are secured by the use over the entire range of the so-called frequency changer or ohmic drop exciter.

It is a curious circumstance that this machine was conceived many years ago but it is just now coming into its own. Mr. Lamme, who is with us tonight conceived the possibility of such a machine years before the necessity for its use in this way arose and for a time it was forgotten. Now the occasion arises and it fits in beautifully and makes

possible the operation of induction motors as adjustable-speed machines.

Without digressing too far into small details, Mr. Crosby mentioned the matter of transformer taps in Mr. Stoltz' diagram. These taps could be reduced to a minimum by the use of a suitable voltage regulator since their function is to adjust the voltage applied to the frequency changer to correspond to the speed at which it is desired to run the main induction motor.

With Mr. Sykes I should like to congratulate Mr. Wright on a very clear presentation in simple language of a very complicated set of technical phenomena.

E. Friedlaender: Is this regulating set taking sufficient care of the fly-wheel effect some of our mills may require—i. e., can we get 10 to 15 per cent. slip for short, heavy peaks and how does it affect the torque, especially when running above synchronism?

J. D. Wright: Answering Mr. Friedlaender's question regarding fly-wheel effect I wish to say that the speed regulation of the equipment which I have described is just slightly more than that of an ordinary induction motor, unless some special provision is made to obtain increased slip. The only reason that the main motor has a greater slip under load with the regulating equipment than without is because of the slightly increased resistance in the secondary circuit of the motor. The main motor without regulating set might have a slip of 3%; with the regulating equipment the slip might be 4 or 4½%. Provision can be made for a greater slip than this if desired. Ordinarily the regulating equipments are supplied with main motors which drive continuous mills where there are no short heavy peaks and where the fly-wheel effect need not be great.

O. Schaumberg: I would kindly ask Mr. Wright to explain to me how the slip of the induction motor is affected when operating below or above synchronism.

— In other words, say we have a 500 h.p., 18-pole, 60-cycle 3-phase induction motor and let us assume the motor is designed to operate at a full-load speed of approximately 390 r.p.m. base speed without secondary resistance or the auxiliary equipment in.

The question now, Mr. Wright, is, will the slip be approximately the same at 20% below and 20% synchronous speed, or what would be the same; will there be a drop in speed of approximately 10 r.p.m. at 360 and 440 r.p.m. when full-load is applied to the motor at the respective speeds?

J. D. Wright: It might drop below synchronous speed. If it operates above it might drop 1 or 2 per cent. below and then return above synchronism when the load went off. If the motor is running below synchronism the action would be the same.

If the motor is running 20% above synchronism with no load and a load comes on the main motor it will slow down such an amount that the increased current, which will flow due to the increased voltage on the regulating machine, will be sufficient to send through the rotor windings enough current to enable the motor to develop the required torque.

I noticed in one of the announcements sent out that this paper would discuss operating conditions, but that was impossible as there is no double-range equipment now in operation. Several equipments will, however, be in operation in the near future and some very interesting operating data should soon be obtained.

The main reason for presenting the paper the way I did was because many questions have been asked regarding the operation of the main motor above synchronism and how it was possible for the motor to develop torque at and above synchronism. I thought that a description of this sort might prove interesting to steel-mill men.

ALTERNATING CURRENT PHASE-WOUND MOTORS VS. ADJUSTABLE SPEED DIRECT CURRENT MOTORS

By D. M. PETTY

A direct-current shunt-wound motor with constant voltage impressed on both its field and armature will fall

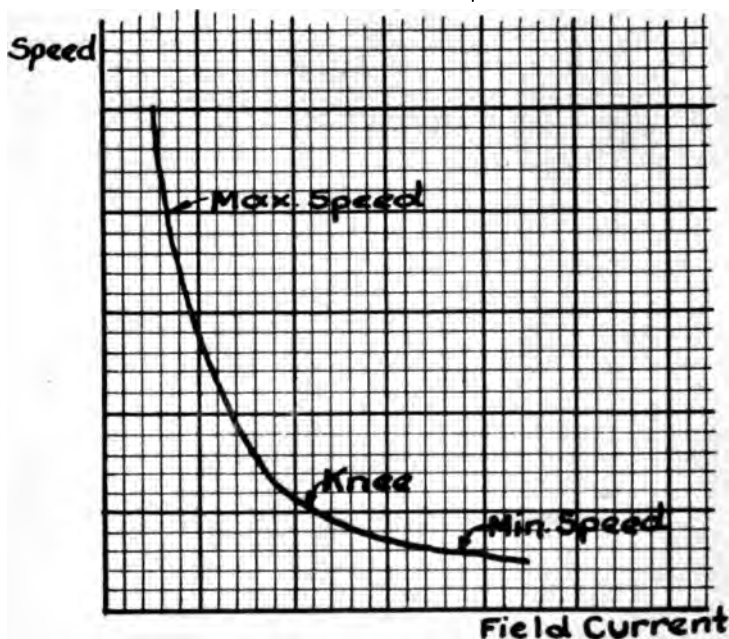


Fig. 1

off very little in speed when the load is increased from no-load to full-load.

There are two factors which help to hold up the speed: one is the increased resistance of the field winding due to

rise in temperature, and the second the effect of armature reaction in weakening the field as the load increases.

The fact that the speed of a given d-c. motor is a function of its field strength, makes this the ideal way to obtain speed adjustment.

The characteristic speed curve of a d-c. motor is shown in Figure 1.

It is well known that the weaker the field strength the higher the speed of the motor, and with a given machine this means the smaller the field current the greater the speed.

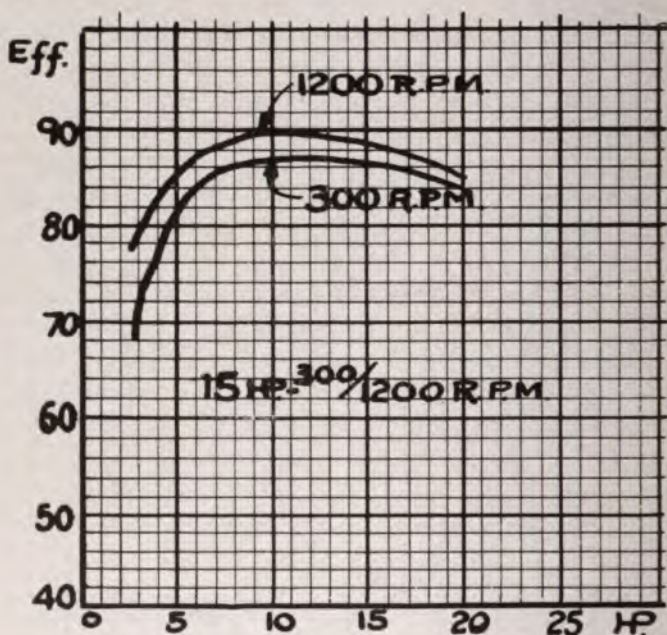


Fig. 2

The field can be weakened until bad commutation begins, if the armature is properly designed to stand the increased centrifugal strains.

Bad commutation starts when the field is weakened to such an extent that the armature reaction becomes excessive in comparison to the field strength.

The minimum speed occurs at maximum field strength, which with a given motor is when the field windings are

across the line. The designer of adjustable-speed motors puts this point just below the knee of the saturation curve, as shown on Figure 1. To obtain a greater field strength and consequent lower speed would require a much greater proportionate number of ampere-turns on the field poles than an equal change of field strength at some point back of the knee of the curve.

The location of the knee of the curve is determined by the permeability of the iron used in the magnetic circuit. Therefore, we find in adjustable-speed motors cast or rolled steel frames instead of cast iron and in some extreme cases soft sheet-steel is used.

As a general proposition the efficiency of an adjustable-speed motor increases with the load and with the speed.

Figure 2 shows the efficiency curves of a typical d-c. motor rated at 15 h.p., 220 volts, 300 to 1200 r.p.m. It will be noted that the 300 and 1200 r.p.m. curves get closer and closer together with increase of load; this is due to the I^2R losses becoming the greater factor in the total losses as compared to the so-called constant losses.

The torque of a shunt-wound motor is the product of its field strength and armature current. Therefore, as we weaken the field to obtain high speeds the torque falls off in the same ratio that the field is weakened and the speed rises.

The characteristics of the polyphase induction motor are similar in a great many ways to the d-c. shunt-wound motor; its speed falls off from no-load to full-load just as in the shunt-wound motor.

This drop in speed, known as the "slip", is necessary in order that voltage may be generated in the rotor and this voltage is proportional to the slip. The resistance of the rotor circuits determine the current with a given slip and the currents in the rotor enable it to exert torque.

With a given motor, as the load increases the slip increases and the necessary rotor currents are therefore produced.

This action continues until greater slip does not produce greater rotor current and therefore no greater torque and the motor stalls.

This is known as the breakdown point of the induction motor. It has a definite value for a given motor.

By arranging the circuits of the rotor so they can be brought out to slip rings, external resistance may be inserted in the rotor circuits and adjusted at will.

Increasing the rotor resistance makes it necessary to have a higher voltage in the rotor in order to produce equal currents and consequent equal torque, therefore greater slip is necessary to carry a given load.

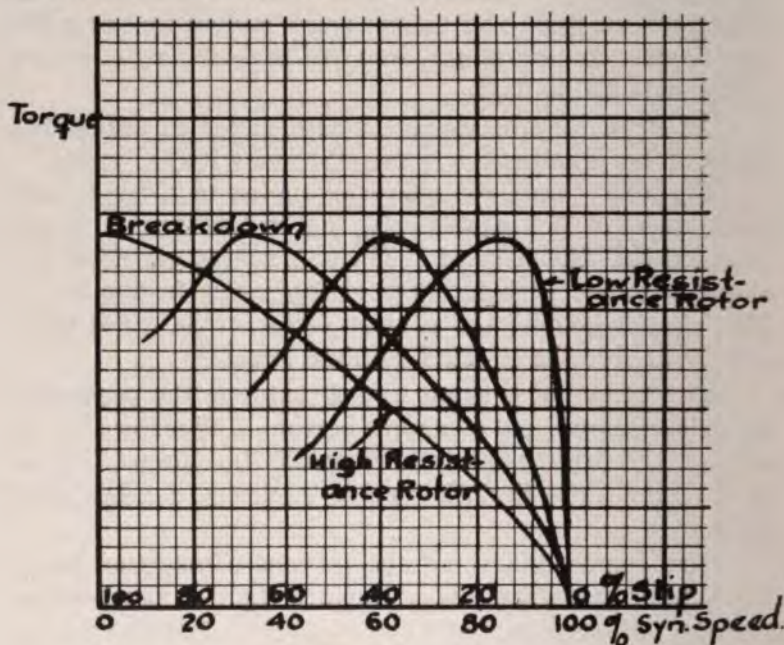


Fig. 3

Figure 3 shows the speed torque curves of a given induction motor with three different values of rotor resistance.

It will be noted that the breakdown torque is constant, but moves toward standstill as the rotor resistance is increased.

This would seem to be a rather easy way to control the speed of an induction motor, that is, the slower the speed required, the greater the rotor resistance would have to be for a given load.

Ordinarily, induction motors are designed to have from 250% to 300% full load torque as the stalling torque, and with minimum motor resistance, that is, short-circuited rings, the stalling torque is at about 80% speed or 20% slip.

The efficiency of the induction motor is almost directly proportional to the per cent of synchronous speed at which it is running. This is easily explained because the torque is dependent on the stator flux, which is approximately constant, and the rotor current. The greater the voltage required in the rotor to produce the necessary current, the greater the losses in the rotor, and we have seen that the greater the slip the greater the voltage in the rotor.

This falling off in efficiency in decrease of speed also limits the capacity of the motor, that is a 10 h.p. motor so rated with short-circuited rotor is only good for about 5 h.p. with sufficient resistance in the rotor to give one-half speed.

Further objection to this method of adjusting the speed of an induction motor is that the speed for a given rotor resistance varies with the load. This can be seen on any of the three curves in Figure 3.

The heavier the load the greater the slip. If the load is of a shifting nature the speed will also shift. The change in speed with change in load is, however, dependent on the rotor resistance, that is, the higher the rotor resistance the greater the change. This can also be noted in Figure 3, by comparing the right hand curve of low to the left hand curve of a high resistance rotor.

In this respect we can say that an induction motor with a low resistance rotor has characteristics very much like the shunt-wound d-c. motor, while one with a high resistance rotor is more like a heavily compounded or series-wound d-c. motor.

In trying to classify the work for d-c. shunt-wound motor and phase-wound induction motors, we shall not attempt to point out all the different kinds of machines and other applications on which they may be used, but rather to give a few typical examples and show why one is more suited than the other.

We also want to point out the fact that in some cases other factors, than the choice of motors according to their

qualifications for the work, must be considered as of prime importance.

For instance, a plant which has only a-c. must, in order to get d-c. convert it either with a motor-generator set or rotary-converter.

The relative merits of these two methods of conversion have been discussed many times, but it is sufficient to say that with a motor-generator set the losses due to conversion are from 14 to 20%, depending on the load factor on the unit or substation and with a rotary-converter from 10 to 15% depending on the same conditions.

If a machine shop is under consideration and a lot of machine tools requiring individual drive is the load, shunt-wound d-c. motors are by far the best solution, because the speed of the d-c. motor is constant with a given setting of the controller, while with a phase-wound induction motor this is not true. Also, the losses in efficiency caused by running on half-speed would be excessive with the phase-wound motor. These two points of superiority of the adjustable-speed d-c. motor almost make it supreme in the machine-tool field.

In the case of heavy flywheel machinery the slip ring motor can be used to advantage, for after the machine is accelerated the load is fairly constant and changes in speed are not of serious nature unless they be in the nature of overspeeding. When overspeeding is of great importance, the induction motor is more reliable than the d-c. shunt motor, because a loose connection of high resistance in the field circuit can easily cause an increase of 50 or even 100% in the normal speed of the shunt-wound d-c. motor. This is of special importance when machines using circular stones are under consideration.

Fan drives where volume and pressure are adjusted by the speed of the motor is a typical example of the kind of load a slip-ring motor can handle with no trouble so far as variable load is concerned, because the load conditions do not change except when the speed of the fan is changed.

Take, for example, the fan driving the gases through the waste-heat boilers on an open hearth furnace.

A large portion of the time full draught is wanted, but there are times when three-quarter or half-draught is wanted.

A d-c. motor will undoubtedly do the work very satisfactorily, but in some cases d-c. current supply is limited, due to limitations in substation capacity or other causes. The question then arises as to whether additional substation apparatus shall be installed or can slip-ring a-c. motors be used.

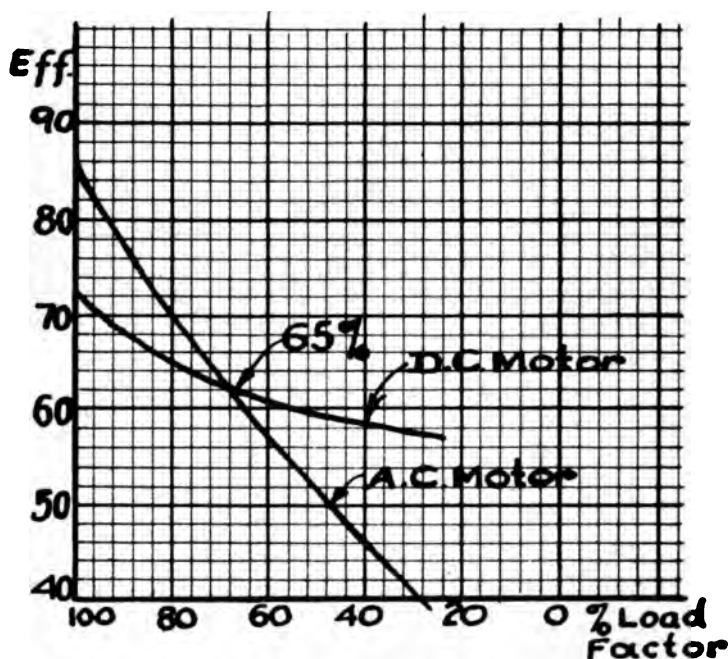


Fig. 4

The following is a general analysis of the problem:

The d-c. motor has an efficiency at full-load high speed of about 90%.

The same motor has an efficiency at one-half volume and one-quarter pressure of fan, one-half speed of motor and one-quarter load on motor, of about 73%.

The efficiency of a motor-generator set will average 80% or a total efficiency of 72% at full-speed, full-load of motor and fan, and 58.4% at one-quarter load, one-half speed.

If we assume 80% running time at full-speed and 20% at one-half speed, the average all-day efficiency is 68.2%.

A phase-wound induction motor of the same full-load speed as the above d-c. motor, has about the same efficiency, that is, 90%. At one-half speed one-quarter load, it has an efficiency of 44% approximately.

The all day efficiency of step down transformers of modern design and 100 kw. capacity will be at least 96%. The total efficiency will then be; full-speed, full-load, 86.4%; one-half speed, one-quarter load, 39.6%.

Assuming the same running conditions as before, we have for the average all-day efficiency, 77%.

Figure 4 shows two curves plotted with load factor as a base and all-day efficiency as ordinates.

The meaning of load factor in this case is a little different from that generally accepted. It is the actual horse-power-hours divided by the full-load in h.p., times the actual running time.

All-day efficiency means the sum of the efficiency at each different load, multiplied by the running time at that load, divided by the actual running time.

These curves cross at 65% load factor, which would mean that with a 65% load factor or better, the a-c. phase-wound motor has a higher all-day, over-all efficiency, than the d-c. shunt motor, but where the load factor falls below 65% the d-c. motor has the best efficiency.

With a 100 h.p. load the saving of 1% in all-day efficiency means 18 kw-hrs. in 24 hours. With current at one cent this amounts to 18 cents per day. Higher cost of current makes the saving greater, but steel mills should get power for that figure or less.

The value of efficiency is sometimes over-estimated. A fan supplying air to a heating furnace in which the billets are heated for a rolling mill is a very important link in the chain, if the link fails the mill shuts down and production must stop.

If the wasting of a few per cent. in efficiency will prevent a shut-down on the mill it is well spent.

Aside from efficiency some of the most important items to be considered in the choice of motors for a given work are:

First—Reliability.

The d-c. motor is a very reliable machine, its most vulnerable point being the commutator.

Against the commutator of the d-c. motor, we can balance both the bearings and slip rings of the a-c. motor, as both together will give in most cases less trouble than the commutator of the d-c. motor. For dirty conditions coupled with high temperatures, the a-c. motor will stand up best.

So far as starting apparatus affect the operation of the motors, the points are about balanced.

Second—Flexibility.

There is no question but that the d-c. motor will lend³ itself to a wider range of speed than the slip ring a-c. motor; a speed range of 6 to 1 is feasible with the d-c. motor, while 2 to 1 is the limit with a standard slip-ring motor.

Further, the speed regulation of the d-c. motor is good, while the slip-ring motor running at reduced speeds has very poor regulation.

Third—First Cost and Floor Space.

In floor space the d-c. motor has a slight advantage.

In first cost the a-c. motor has some advantages, although not very great when the motor alone is considered; but when the cost of transforming apparatus is included, the a-c. motor has a very marked advantage.

CONCLUSIONS

First: That on account of the poor speed regulation and limited speed range of the a-c. motor, d-c. motors should be used for machine tools and other applications where these qualifications are of prime importance.

Second: That adjustable-speed drives of all kinds requiring a large percentage of operation on low speed should be d-c.

Third: That drives requiring a maximum speed reduction of 50% below full-speed and that have a falling power curve with reduced speed and approximately constant load except upon change of speed, can be satisfactorily handled with a slip ring motor and economically handled if the load factor is fairly high. These conditions are met

with in blowers and fans and to a certain extent in centrifugal pumps.

While it is without the scope of this paper to discuss other forms of adjustable a-c. motors, it is not out of place to say that there is on the market today several schemes which involve auxiliary apparatus, the purpose of which is to return either to the line or to the load the power which is wasted in the resistance of slip ring motor control as discussed in this paper.

There are also some a-c. commutator type motors on the market which lend themselves to speed adjustment.

DISCUSSION

J. C. Reed: This has been a very interesting and instructive paper and I do not know that I can do more than emphasize a few points.

The question of whether an a-c. or d-c. motor is to be used for a certain job is constantly arising and it is not possible to decide in a general way, since local conditions frequently will have a bearing on the answer.

In large steel plants, where alternating-current is usually generated, it is a good policy to use an a-c. motor if it can be made to successfully do the work, because this reduces the amount of converting machinery required to operate the plant. It also saves the conversion losses. Sometimes it may be advisable to sacrifice some slight advantages the d-c. motor may have and still use the a-c. motor.

There are a great many machines, the operation of which requires a variable-speed motor and hence, except in a few special cases, a d-c. motor will have to be employed. There are, on the other hand, a great many cases where this is not necessary and an a-c. motor can be used. I have found a third class in which a variable-speed motor is called for but is not required and it is usually called for because the mechanical engineer of the shop or mill superintendent, or possibly the machine-tool builder does not know what speed he will desire to run the machine. Frequently he desires to start at a low or moderate speed and

then increase it as the operators become more expert, but finally they get to the speed they want and the variable-speed motor can be replaced with a constant-speed motor. It is a good plan to make an investigation once in awhile and see how many of your variable-speed motors are being used as such. Sometimes I have had the field rheostats "doctored" in such a manner that the resistance cannot be varied, and if this brings no kicks I change that motor and put in an a-c. motor, being careful to preserve the same speed on the machine. This policy keeps down the d-c load.

The question of whether or not an exhaust fan requires a variable-speed motor, depends upon the amount of variation in the draft which will be required. The simplest way is to use a constant-speed motor and put a damper in the line, and in some cases this will work out as cheap as to use a variable-speed motor. A slip-ring motor can be used as pointed out by Mr. Petty, but there is little to choose from, when it comes to maintenance between an a-c. slip-ring motor and a d-c. motor, especially in the smaller sizes and the losses will work out about the same as to use a damper, while with a d-c. motor the conversion loss is always with you and may prove to be higher than the other methods.

To my mind the use of the slip-ring motor is confined mostly to the larger sizes, where the poor starting characteristics of the squirrel-cage motor renders its use not advisable, or where it is desirable to secure a slight reduction of speed, so as to take advantage of the stored energy of a fly-wheel. It is sometimes possible to construct a squirrel-cage motor for similar purposes without impairing the net efficiency of the installation.

Some years ago I installed in our bridge department a number of three-ton traveling jib cranes—we call them wall cranes—for the purpose of handling the air riveters, the scheme being to move the riveters along the work from rivet to rivet. We had previous to this used a number of similarly constructed d-c. cranes, but as this was before the development of the solenoid controller, we experienced great expense and frequent delays, due to the failure of the controllers which were operated by means of ropes from the floor. The use of the high resistance rotor motor, designed for starting service only, done away with the controller,

since it could be started, stopped and reversed by means of small double-throw oil switches which would last for several months without inspection or repairs.

Mr. Petty has brought out all the features of the series shunt and compound-wound motors. The series motor is probably the most widely applied motor in steel mills, since they are used almost universally for crane and table work. A-c. motors have been used for this service but never became popular, because of the more complicated wiring and control apparatus required; also because of the small clearance between rotor and stator which necessitates the frequent changing of bearings and the fact that to replace a-c. motor parts takes a considerable greater length of time than that required for d-c. motors. My own experience with a-c. motors for table work convinced me that the d-c. motor is much superior.

Clark S. Lankton: I do not know as I have very much to say. Mr. Petty did not include squirrel-cage motors in his paper, but limited same to wound-rotor motors.

It has been my experience that often-times you can use a squirrel-cage motor and get your speed reduction through adjustable gears. If you can use sliding gears and a squirrel-cage motor, then your motor is always running at the same speed and you do not need motor slip for this arrangement. I know of some lathes that were made that way and they were satisfactory. As Mr. Reed says, I believe that in a good many of the cases where they want adjustable speed, they could get along with constant speed.

I am not as favorable to the slip-ring type of motors as some people in this organization. An a-c. motor running on resistance does not appeal to me as an ideal way of doing it. The motor is sluggish on the low speeds, it does not take the load as quickly; the speed variation is greater. In other words, the regulation is poor and a great deal is lost in efficiency.

R. F. Gale: I would like to know more about the starting of large a-c. motors, under loaded conditions. Suppose for example you had an a-c. motor on an accumulator pump, and the question was whether this motor should operate all of the time, or cutout at the end of the accumulator travel, cutting in again at a reasonable distance from the

lower end of the stroke. I would like to hear from somebody regarding this.

In 1908 I had an experience with an a-c. crane. The crane was erected over a moulding shop, to be used to draw patterns out of the sand. When the controller was on the first point nothing moved. Upon moving it to the second point, the pattern came out of the sand all at once, dragging the sand with it. This condition could not be improved until the motors were changed over to d-c. However, a-c. apparatus might have been improved since then.

Chas. C. Kafer: I would like to bring up the question of variable speed. We have sixteen waste-heat boilers at the present time, operated by variable-speed d-c. motors. The question seems to come up that it is desirable after a furnace has been rebuilt. Now the motors we have at the present time are 300 to 600; that is, two to one variation. After the furnace is rebuilt we can run that motor in the neighborhood of 350 to 400. It takes care of the draft, waste heat, steam, and everybody seems to be satisfied with it. But after it is on, instead of 300, 400 or 600, they want 650 on there. That is where the electrician is up against a proposition. The heater says he can give us heat, but when they shut the boiler down it is up to the electrician to find out if he is going to run that motor with this speed or speed the motor up. That seems to be the proposition I am up against in trying to accommodate the different people on the floor.

If Mr. Petty has the proposition he spoke of worked out, it seems to me he has solved that question on the variation of the a-c. motor. I am sorry to say we have not any installed at present, but if he has as much trouble in getting the variation on the a-c. as I have on the d-c., I am sorry for him.

A. M. MacCutcheon: With reference to Mr. Petty's paper, it may be interesting to review the theoretical considerations involved in securing a speed variation on motors; in what way the various factors are interrelated and why up to the present time the d-c. motor has offered the only practical solution to the problem of securing various speeds which, after setting, shall remain practically constant with variation in the required torque. By the required torque

we mean that force at the shaft which resists the turning of the armatures. The horsepower, of course, equals the torque times the speed.

In all motors a-c. and d-c. the rotating part must develop a torque equal to the outside resisting torque and further the impressed voltage must be balanced by a counter-voltage produced in the motor, enough less than the impressed voltage to allow a current to flow sufficient to produce the required torque.

The torque produced in a motor depends upon the current flowing, the number of conductors and the strength of the magnetic field. The counter-voltage depends upon the rate at which the field is cut, the number of rotor conductors and the strength of the magnetic field.

In a d-c. motor of shunt characteristics, the strength of the magnetic field is independent of the armature current. Consider the two equations:

Torque equals current, times rotor conductors, times magnetic field.

Voltage equals magnetic field, times speed, times number of conductors.

The speed may be changed by changing the magnetic field as is apparent from the voltage formula. For example, with one-half the magnetic field, the conductors the same, external voltage the same, the speed is doubled. With a constant torque the armature current must be doubled, when the magnetic field is weakened to a one-half value. Constant torque and double speed give double horsepower.

With constant horsepower, when the speed is doubled the torque is one-half. Since the magnetic field is one-half, the torque one-half, the current is constant. This is the usual condition on field weakening motors.

Now consider a change in the torque and its effect upon the speed with a certain strength of magnetic field. Flux is constant, number of conductors are constant, impressed voltage is constant. Therefore, the speed is practically constant. The change in torque is secured by the change in armature current and a very slight drop in speed gives a large increase in armature current. It is this characteristic of the direct-current shunt motor which gives it its

speed, flexibility and control. The torque and the speed are independent.

The series motor can be studied in the same way, but here we find that the magnetic field is dependent upon the torque since a change in torque means a change in armature current which in turn passes through the field. An increasing load results in a decreasing speed.

In considering alternating-current machines, the voltage applied must be balanced as in d-c., but this balancing is not dependent upon the speed of the rotating part as in direct-current. Further, the external torque applied to the shaft must be balanced as in direct-current. With the ordinary type of slip ring motor, with resistance in circuit in the secondary, the change in torque is accompanied by a change in speed as in the series type d-c. motor and the motor is, therefore, not adapted for machine-tool and similar drive where a constant speed of a fixed value with a change in torque is desired.

We will note briefly how this change in torque results in a speed change. With an increasing torque, it is necessary for a larger current to flow through the rotor conductors. On the squirrel-cage motor a very small percentage of slip results in a large increase in rotor current, but on the slip ring motor a greater amount of slip is necessary to produce the voltage which will force the increased current through the external resistance. A change in the external resistance will change the speed for a certain necessary torque. As soon as the external torque is removed the motor comes up to practically synchronous speed.

To summarize: A constant speed with varying torque is easily obtained on a d-c. motor since the speed can be made independent of the torque, whereas in the ordinary commercial form of alternating-current motor the change in speed depends upon the change in torque.

C. W. Conrad: I agree with the gentleman who stated that a constant-speed motor can be used many times where it is thought that a variable-speed motor is required.

We have only a few phase-wound motors in our plant. Fifteen of these are geared to rolls where it was thought that variable-speed would be desirable. However, they are operated at maximum speed which gives the most satisfac-

tory results. We have a large slip-ring motor that drives an air compressor, and of course the resistance is used only for starting. The phase winding is necessary in this case because the starting torque of the compressor, although supposed to be low, is extremely high under the conditions which it operates. We also have some small adjustable-speed direct-current motors on some special machines, but I have noticed that these have been operated without speed variation since the correct speed was obtained soon after the machines were installed. These variable-speed motors represent a small percentage of the total number installed; over 90 per cent. of our motors are squirrel-cage induction motors driving line shafting. When it is possible I prefer to obtain speed variation on machinery by the use of adjustable gears or cone pulleys when using alternating-current motors.

The question of power factor has not been brought up. In case power is purchased and there is a penalty for low power factor, it is possible that the direct-current motor could make a better showing for itself in Mr. Petty's efficiency-load factor curve. That is, if the efficiency is reduced to a dollar and cents basis. However, I might add that the power factor of the phase-wound motor does not vary through its speed range.

I think that Mr. Gale asked about accumulator motors. Perhaps Mr. Gledhill can answer his question about them, because I know that he has some.

J. S. Rowan: I think that one of the most important things to be considered in deciding whether to use a-c. or d-c. is the question of starting torque, and if a-c. is decided upon, this feature largely determines whether to use a slip-ring or squirrel-cage motor where speed variation is not necessary. A great deal of trouble is caused by using squirrel-cage motors when a slip-ring motor should be used and even when the latter is used it is often necessary to use a larger motor than would be required on d-c. to provide sufficient starting torque to prevent stalling and consequent burnout of a-c. motors due to insufficient starting torque. This leads me to suggest that more attention be given to this point. Where adjustable-speed is desirable, the paper and discus-

sion easily show that for most cases d-c. should be used whenever same is obtainable.

S. P. Johnson: In reference to the variable-speed direct-current motor, I believe the shunt-wound interpole type is the ideal type of a motor drive for machine-tools on account of its wide range of speed and flexibility for adjusting same, especially when automatic control is used, together with its dynamic brake feature, which means saving of time, and, therefore, increasing the efficiency of the machine-tools, which permits greater output, and for which every concern looks for.

Further, I would state that 95% of our machine-tools are equipped with this type of motor.

When alternating-current motors are used for the same purpose, I would say that the best suitable motor would be the one wound for four different speeds, namely, 600, 900, 1200 and 1800, and with some additional slip gears in conjunction with same you get a fair variation of speed.

The a-c motor has its advantages in a great many cases, but for machine-tools the direct-current motor is the most suitable.

Leonard Work: I think that the most important point Mr. Petty brought out in his able paper is the greater reliability of the a-c. motor over the d-c. motor. There are classes of work in which the d-c. motor is almost necessary, as has just been mentioned, where a considerable variability in speed must be had. But there are many other applications where either class of motor may be used. The direct-current motor cannot compare with the alternating-current motor when it comes to reliability, and, personally, I make it a rule to never use a d-c. motor unless the conditions absolutely require one, just on the grounds of reliability. With the alternating-current motor we do not have commutation troubles, breakdowns of insulation from field discharges, and so forth. In the bar-wound motor we have almost as simple construction as a plain shaft with two bearings, and the motor will withstand a great deal of misuse on account of its simplicity of construction and its mechanical strength.

There is one type of cage-wound motor having high resistance and rings which has a high starting torque with a

moderate starting current. This motor should have a wide application. In competition with a direct motor, however, it may not have quite as high efficiency as the latter, but on the other hand, its reliability will be certainly greater and considerably outweigh the difference in efficiency. While a few cents a day might be saved in the employment of a direct-current motor, the benefits of that efficiency may be wiped out completely in a single breakdown. In short, there is infinitely less trouble from stoppages or breakdowns with a-c. motors of polyphase type than with d-c. motors of any type.

The question of the proper application of these two classes is neither generally nor accurately understood. Neither type of motor is adapted to all purposes, but the field in which the a-c. motor cannot well be applied is very restricted indeed, and with the rapid development of the multi-speed induction motor this field is becoming smaller and smaller. Each case of motor application should be decided on its merits and with a knowledge of the requirements. Often the requirements are more theoretical than real and a variable-speed d-c. motor will be installed only to have its variable-speed features never used. In such cases, where both systems are available, the more reliable induction motor should be installed. Overhead cranes are in successful daily operation using either system, but the success depends largely on the character of work the crane is required to do.

Baxter Reynolds: I have been very much interested in the remarks relative to a-c. motors, and particularly in reference to machine shop drives and in some cases crane drives. I know that in our own shop (we have a plant where we manufacture electrical machinery) we have changed over practically all our motors to a-c. We find the maintenance is practically nothing, and we have cut down greatly the number of interruptions.

Any one in a plant where they have a number of d-c. motors knows the maintenance on those cranes in the course of a year.

Now in reference to machine-tool drive. Wherever we can we put in an a-c. motor. We have both a-c. and d-c., but are gradually replacing all our d-c. with a-c. because we

find in almost every case machine-tool can be driven with a constant speed a-c. motor, and where it cannot we have a scheme we have worked out, which lowers the counter-shaft and puts it right back of the machine, and by using a 2 to 1 slip-ring motor we can get variations very easily by changing gears or belts. There is no question but that an a-c. is more reliable and will have a good deal less maintenance.

It is interesting to hear this discussion, because 10 or 15 years ago this discussion would not have seemed possible.

Norman P. Farrar: The company I represent would really prefer to push the use of a-c. electric traveling cranes because we have a mechanical load brake that is absolutely safe and positive and will withstand severe service for years without renewals. Dynamic braking cannot be used for a-c., therefore mechanical brakes have to be resorted to, and as the majority of brakes heretofore used have been very troublesome, we would have an excellent talking point but we always try to bring out the truth to our customers and that is, that a d-c. crane can handle about 50% more work than an a-c. crane.

Ordinarily a crane only handles on an average of about 25% of its rated capacity, or less, and a great deal of the time it runs with no load; consequently the acceleration of the d-c. motor will enable you to obtain much higher average crane speeds than the rated full-load speeds.

Two purchasers of our cranes recently figured this out from the production standpoint, and while their only available current was alternating, yet they considered it to their advantage to install motor-generator sets and use d-c. cranes. They found d-c. speed-control in this case was not required.

Regarding the cost of maintenance which Mr. Reed brought up, I have never heard of any great difference between a-c. and d-c. motors on cranes, although he said he finds that in mill table service the d-c. is cheaper. Many people claim the upkeep is less on a-c. than on d-c., but I think these statements are misleading because some people accept them as facts and think they are applicable to cranes. They neglect to take into account the greater production and much better speed control obtainable with d-c. cranes. The greater production alone, more than offsets any other

consideration. Even if we assume that the a-c. crane motor causes less trouble, you will have to figure on having more trouble with the a-c. solenoid brake than the d-c. magnetic brake, so in this case one would probably balance the other.

Cranes are the only machines with which I am familiar, therefore I am unable to venture any further opinion on the subject.

George W. Richardson: I would like to say that I am one of the unfortunate ones who has no a-c. current around the plant. I have plenty of d-c., and of course have my troubles with that, the same as every one else does.

But Mr. Reed was speaking of punches, machine-tools having fly-wheel effects, where he used a constant speed. We have been doing that for years—of course with a direct-current machine. We have recently put on adjustable-speed motors, our principal reason being to try and get more work out of the men.

Some time ago I had occasion to make some changes on machines, and the armatures of the particular motors after the change ran faster. In putting them on, of course, the men put up a kick right away. I greatly desired to find out what I could do with the men in our shop, so I gradually commenced to raise the initial pressure in the powerhouse. I did not jump it all in one jump, but I started from 220 to 250, and I did it gradually. The men went along making more for the company and forgot all about it until the punches commenced to work at least three or four punches more. Now we have placed in variable-speed motors for that same purpose. There is some machinery, that when the punch requires a little lower speed a man cannot handle the material as fast, and we find we have other material and other punches, perhaps with the same punch, where we could get the work out a little faster. So by educating the operator to start his machine faster, instead of 24 punches, we got them up to 28, 29, 30 and even more than 30 punches a minute, which means the men make more money and also the company.

We find the adjustable-speed motor comes in there pretty good, but just as Mr. Reed has spoken about, many times they do not really know just what speed they do

want when you first put them in, but after they get it going they find out they are either too fast or too slow.

I would like to ask Mr. Petty in reference to a motor drive for exhaust fans for waste-heat boilers. On our waste-heat boilers we use turbine engines, and we have found some little trouble—most all the steam that the boiler makes goes through the turbine, and we want to overcome that in some way.

On the first boiler we had was an engine, and we had a considerable amount of trouble with the bearings getting hot and the engine rattling itself, but recently the new ones placed in were turbine-driven engines, and, as I say, it takes a considerable amount of steam to run them, and I would like to know from the experience of those that have run motors from that angle of work how much more efficient they are than the engine drive.

John H. Gledhill: When we first started to manufacture shells, it was decided to use current from the Philadelphia Electric Company, and we found that a great many men who were selling machines asked for direct-current motors. We did not care to go into the direct-current motor question at all at the time, and we finally decided on all machines being driven by induction motors. Everything went very well for the first job, but when it was necessary to purchase other machinery, I found that the men in charge of the machine-tools were leaning toward the direct-current motors because they could not get production from the machines driven by the constant-speed induction motors. From this, I believe the variable-speed direct-current motor would be the best for that kind of work.

The hydraulic pump question came up and we purchased some pumps and decided to operate them automatically. We bought two pumps and two controllers for 2200 volts. We have had them in operation for about fifteen months, and they have been doing satisfactory work, but the upkeep is considerable. When it was necessary to purchase other pumps, it was decided to make use of motors that would operate continuously, the water to be mechanically by-passed when the accumulator had reached its limit of travel. This was done at the Standard Steel works, where a battery of eight pumps was installed and which are giving

satisfaction. Of course, there would be times when some of the motors would be operating without any load; therefore it is a question as to whether this arrangement is more desirable over the automatic starting panels which must start and stop at the limits of travel of the accumulator.

I believe if we had decided on the lower voltage instead of the 2200 volts for the first two motors, it would have worked better, for I like the operation of it very well. A bad feature of it is, of course, the hard pull on the line when starting the motor so many times throughout the day. There is also the question of economy, but I have not had time as yet to figure that out. We have, however, decided to take out the high voltage panels on account of the danger attached thereto. We found that many times the magnets did not work and we had to have a man there pretty nearly all day long. The system that gives the least trouble, I believe to be that installed with the by-pass valve equipment.

George W. Richardson: I think constant speed is most satisfactory, because there would be less troubles in overloading an a-c. motor, or constant-speed motor, than there would be if you would use a variable-speed motor. In my own shop, I find they will overload the motor very heavily before they change in gears. I find with that system we have to use a great deal of argument against the superintendent of a shop to stop the men from doing that kind of work. There is the same tendency with the variable-speed motor—they will speed it up and put on heavy cuts.

I had an experience with that not long ago, when I put a variable-speed motor on a reversing plate planer, and I immediately jumped the speed pretty high for them to start. I jumped from 18 to 29 feet a minute, and the motor done very well under it, but as soon as my back was turned, they commenced to gouge a little bit more and ran the current up on the machine something like 200 amperes on a 60 ampere machine.

If you have a constant-speed, or an a-c. motor, they will just make that cut accordingly. If you put in a machine large enough, and they cannot vary it in any way, I think it is good for the electrician. If you can keep the d-c. motors down to load, they will not give you much trouble either. I have some machines running for twenty years that did

not give me any trouble at all, but I have some that give me trouble every week or so.

John H. Gledhill: We have a couple of cranes equipped with alternating-current motors on munition work, and a little over-load would stall the motors. This type of crane would not be very satisfactory for lifting large locomotives.

George W. Richardson: I wish to say that when the a-c. motor was first brought out for commercial use, we had quite a number of salesmen coming to our place and they got our manager at that time, who was Mr. Roberts, very much interested in a-c. We of course started out with d-c. and he came and said, "Richardson, I have some nice curves down there; you will have no trouble with them." I said that would be very nice for me, and asked him if it would be satisfactory to him. He said, "You are always complaining about overloading your motors. I understand you cannot overload these motors." I replied, "If we had a load of just a little more than the capacity of the crane and we wanted to take it off the car, would it be satisfactory to you to get the riggers or put in a d-c. If you want to try it out, put in a little plant and try one or two motors." He never tried it, and we never got a-c. motors there. Since then the a-c. has been improved.

Harry E. Odenath: I would say that one of our friends seem to favor the a-c. motors for crane service, and I should like him to tell us just how he would overcome the objections made by those who favor the d-c. motors.

D. M. Petty: I am very glad indeed that you said for me to answer some of the questions. I do not think, if we were to stay here the rest of the night, we would finally decide the question of which was the best motor to use, a-c. or d-c., but I feel that the discussion that has come out on the different motors has been of material benefit to us all, and I am sure it will help us in solving our future problems.

If we have a-c. and d-c. power equally available, at the same cost of delivery, it is decidedly different from the condition that obtains in plants that are buying power and large plants that are manufacturing their power as a-c.

So far as the waste-heat boiler problem is concerned, I feel that we have a lot to learn along that line. I think the greatest trouble is the fact that we do not seem to know ex

lem seems to be in ample spacing in the oil switch contactor and the passing of each individual phase through a separate tank.

We started out the first installation of that kind and had two contactors all in one tank, one phase running straight through to the induction motor, and we had trouble due to the fact that the current would jump across from one phase to another, thus short-circuiting the line, which opens up the overload switch, sometimes opens it in rather an unceremonious fashion, blowing the tank off, etc. But that has been largely overcome by putting the contactors in separate tanks.

To my mind, it is not a question of the motor; it is a question of the oil switch design. I think all this trouble can be overcome if ample leakage surface under the oil is provided.

Another problem in connection with starting a-c. motors against this kind of a load, aside from the trouble and maintenance of motors and controllers, hinges on the capacity of the transformers behind the motors and the capacity of the powerhouse behind them. If you are buying power on a maximum demand basis, you have to watch very carefully the starting peaks, and it might pay you in cases of this kind, where very much stopping and starting exists, to let the motor run all the time. But under ordinary conditions, I would say if you had fairly good sized transformers back of the load, it can be operated satisfactorily, using automatic stopping and starting.

The problem of machine-tool drive has been discussed in various ways tonight and from various standpoints, but I feel in any large machine shop, that production is what we are after, and it is the function of the electrical engineer to put a motor on the machine which will deliver the greatest production with the minimum cost. Sometimes I am very sure it would pay to spend a little more money in order to keep up the production, rather than trying to keep down the maintenance cost by putting on a motor which would limit the production, for after all, the production on machine tools, as compared with the maintenance cost of the motor driving the machine, is by far the most important item.

George W. Richardson: For machine-tool work, I am of the opinion that the d-c. motor would work out better than the a-c. It is production as Mr. Petty says, that we want and what they are always shouting for. "If your machine does not fill this requirement, get another one." That is what they will tell you, and I do not think they are going to get an a-c. to fill all those conditions. They have, I understand, an a-c. which can change to four speeds, but I imagine it is quite complicated to do that.

MODERN STEEL MILL CRANE SPECIFICATIONS

By F. D. EGAN

GENERAL SPECIFICATIONS

BRIDGE.

1—Type: This crane shall be known as the no overhung gear, all steel construction type.

2—Girders: The girders forming the bridge shall be "Builder's Standard Design" box girders, and due provision must be made for adequate water drainage. Top cover plates of girders shall be suitably supported to prevent bending under trolley load. All cover plates and cover plate angles shall be one piece for the entire length of the girders. Splices of approved design will be allowed in web plates.

Girders shall be rigidly attached to heavy cast steel end trucks and shall be provided at each end with gusset plates and angle braces necessary to prevent twisting. The design of all parts of the bridge must conform to the Standard Specifications of the Association of Steel Manufacturers.

When specified, a permanent structure supporting beam or beams for use in repairing trolley, shall be located over bridge motor and arranged to allow of its use for repairs on that motor. This structure shall be capable of lifting the heaviest piece of such repairs.

3—End Trucks: End trucks shall be made of cast steel, amply strong to prevent breakage under the most severe strain to be met with under legitimate use of the crane. A heavy safety lug shall be cast across the bottom of each end truck near the truck wheel and one (1) inch above top of rail, to prevent drop of crane in case of breakage of truck pin or truck. No parts of the truck gear shall project below the flange of the truck wheels. Trucks shall be furnished with axle journals as shown on blue-print herewith.

All bearing brackets, unless in body of truck, shall be made of steel and rest on finished surfaces. They shall be fastened to the truck by through-bolts and further held in position by one or more feathers or keys extending the entire length of the base of the bracket and parallel to the shaft so as to hold the bracket in line, independent of dowel pins or body bound bolts.

Trucks shall be made so that center-line of truck wheel is on center-line between truck wheel shaft bearings.

Maximum wheel load for two wheel truck shall not be over 60,000 pounds.

Spring bumpers shall be attached to end trucks to limit bridge travel.

Wheel base shall not be less than 12'-0" center line to center line of truck wheel except on approval of the purchaser's engineer.

4—Truck Wheels: Bridge truck wheels shall be of cast steel centers with rolled steel tires of not less than three (3) inches thick on tread, and not less than twenty-four (24) inches tread diameter. They shall be double flanged with treads accurately finished to conform to standard "T" rail. Wheels shall be pressed onto axle and keyed. The pressure employed for this purpose shall not be less than 9 tons per inch diameter of axle shafts. Bridge truck wheels shall be finished to allow one-quarter ($\frac{1}{4}$) inch clearance on each side of flange. Pressure of bridge truck wheel journals shall not exceed 750 lbs. per sq. in. figured at maximum wheel load on each wheel.

Truck wheel driving gear shall not be greater O. D. than flange on truck wheel.

5—Bridge Drive: Bridge motor brackets shall be built of structural material and shall be attached to girder by suitable angles. These angles shall extend the full depth of the girder and over vertical legs of flange angles. The extending arms carrying the motor shall be supported by heavy gusset plates. Floor plates and brackets shall be stiffened by cross angles directly under the motor base.

Bridge motors shall be bolted to brackets by bolt extending through floor plates and stiffening angles.

The bridge shall be driven by a line-shaft, divided into lengths convenient for handling. The end sections carrying the bridge drive pinions shall not be more than four (4) feet in length and shall be interchangeable at either end of bridge drives.

Line-shaft is to run through standard countershaft bearings on bridge driving motor.

Shaft at motor shall be a short section having a diameter increased under gear seat the same as the hoist shafting to facilitate removing gear.

Other sections on line-shaft except end sections and sections at motor shall be equal in length where possible.

Safety flanged couplings of cast steel drilled to template shall be furnished.

The bridges shall be provided with a foot brake of ample power to control the crane with its full-load in case the current should be cut off while the bridge is traveling. The bridge brake wheels shall be placed on the armature shafts and shall be easily removable therefrom. The brake wheel shall be of steel and shall be of web form, turned all over to insure proper balance.

6—Footwalks and Hand Rails: Two foot walks shall be provided and to run full length of girders, one on each side of crane; floored with checkered plates thirty-four (34) inches wide and provided with

angle hand rail 42" high and an intermediate member twenty-one (21) inches high.

Curb angles along footwalk shall have one leg projecting vertically at least four inches above plates to prevent tools, etc., from being kicked off.

Footwalk on bridge motor side shall be below line-shaft and around motor, where at least fifteen inches clearance shall be provided between the motor and handrail.

Footwalks on opposite girder to be 6'-6" from bottom chord in building, or if there is nothing above crane, walk should be flush with top cover plate on crane girder.

TROLLEY.

7—Trucks: Trucks shall be made of cast steel amply strong to prevent breakage under the most severe strain to be met with under legitimate use of the crane.

A heavy safety lug shall be cast across the bottom of each end truck near the truck wheel and one (1) inch above top of rail, to prevent excessive drop of trolley in case of breakage of truck pin or truck. Pressure of trolley truck wheel journals shall not exceed 750 lbs. per square inch.

8—Trolley Truck Wheels: Trolley truck wheels shall be cast steel centers with rolled steel tires not less than fifteen (15) inches tread diameter and not less than two and one-half ($2\frac{1}{2}$) inches thick on tread. They shall be double flanged with treads accurately finished to conform to standard "T" rails, and to allow one eighth ($\frac{1}{8}$) inch clearance on each side of rail used.

Wheels shall be pressed onto axle and keyed. The pressure employed for this purpose shall not be less than 9 tons per inch of diameter of axle shaft.

Trolley truck wheel driving gear shall not be greater O. D. than flanges on trolley truck wheels.

9—Drums: Hoist drums shall be of sound steel or air furnace iron castings with machined grooves for rope to work in and shall be so designed as to leave not less than two complete wraps of hoisting rope in grooving when hook is in lowest position, and not require overlapping of rope when hook is in highest position. Drum must be keyed fast to shaft, and drum gear keyed fast to drum. Drum gear bore shall not be less than 80% of the diameter of the drum.

Drum shaft to be increased at points of contact with drum in similar manner to other hoisting shafting. These points to be $\frac{1}{4}$ " difference to allow easy replacement of shaft. Drum to be keyed to shaft on driving gear end only.

Pitch diameter of drum shall not be less than thirty times the diameter of cable.

On all ladle cranes the main hoist drums shall be driven by two motors, each through its own train of duplicate gears and either one

capable of handling full load, and to be so designed that the breaking of any gear or shaft will not allow the load to drop.

When the use of a lifting magnet is specified, a hardwood magnet drum with machined grooves for cable to work in shall be provided.

Pitch diameter of drum to be not less than twelve inches, with split collector rings and brush holders arranged as shown on accompanying print.

This drum shall be driven through spur gearing from hoist shafting and be so located as to keep magnet cable free from hoist cable.

If an outside crane, a metallic cover shall be provided to protect collector rings and brushes from snow and ice.

10—Shafting: All hoist shafting carrying gears or pinions to be forged open hearth steel with a diameter at point where gears are located increased by $\frac{1}{8}$ " increments to not less than twice the depth of the key seat.

All connections subject to torsion are to be pressed on and keyed in place. Press fits to be made with pressure of not less than 9 tons per inch diameter.

11—Lifting Tackle: The lifting tackle shall consist of extra flexible six strand, 37 wires, plow steel hoisting cable.

Ladle cranes shall have one set of active and one set of safety cables, either set capable of handling full load.

All sheaves except idler sheaves to be not less than thirty-times the diameter of cable. All shall be protected by steel guards which fit close to the flanges to prevent the rope coming off.

Bottom block shall be of structural or cast steel, hooks shall be steel forgings of capacity not less than 200% of rated load of hoist and shall swivel on ball bearing, so constructed as to exclude dirt.

12—Brakes: Each hoist shall be arranged for electric dynamic braking and shall be adjusted that the speed of the hoist lowering full load shall not exceed that of hoisting under full load, by more than 10%, and the speed lowering light shall not be less than twice full load speed. Main hoist shall be equipped with two electric brakes, no mechanical brakes being required.

One electric brake shall be located on the extension of the armature shaft and the other shall be located on the intermediate shaft. Each brake shall be capable of stopping and holding a load equal to 120% full load. Strap brakes shall be lined with thermoid or its equal. The brake solenoid coils shall be connected in series with the motor, and the wire on strap shall be of section not less than in the motor fields. Solenoid coils shall rest on independent brackets and not on the motor.

13—Limit Switch: An approved type of limit switch shall be furnished with each hoist.

14—Trolley Rails: Rails shall be fastened to the bridge by clamps. The bolts holding these clamps shall be staggered, about three (3) inch centers on opposite side of rails and spaced not more than thirty-six (36) inch centers.

Provision must be made to prevent creeping of rails on girder by stop riveted to girders.

Spring bumpers shall be put on ends of bridge girders, not on rails, to limit trolley travel.

15—Footwalk and Hand Rail: Trolley to have floor plate under motors, shafts, drums, etc., forming a working platform, with provision made for reaching footwalk on either side of crane.

A handrail 42" high with an intermediate member 21" high, shall be provided around trolley.

ELECTRIC EQUIPMENT

16—Motors: Motors shall be furnished by the purchaser, delivered F.O.B., builders works and mounted by builder. Motors will be mill type, with back axle brackets and bearing linings where desired, but without pinions, gears or gear cases. Motors with back axle brackets shall be used on the bridge and hoist drives.

Following are the diameters of the back axle bearing that can be used:

10 h.p. and under	3- $\frac{1}{4}$ "
10—15 h.p.	3- $\frac{3}{8}$ "
15—30 h.p.	3- $\frac{3}{8}$ "
30—50 h.p.	4"
50—75 h.p.	4- $\frac{1}{2}$ "
75—100 h.p.	5"
100—150 h.p.	6"
150—200 h.p.	7"

Builder shall state what size motor he will use in each case on crane and also if back axle bearings are required on drives, other than bridge or hoist.

17—Controllers: Controllers will be furnished by purchaser. All data regarding same, necessary to design crane, will be furnished by purchaser.

18—Safety Switches: The two double pole knife switches shall be furnished, wired in series; one mounted in metal box in operator's cab, and the other mounted in metal box on the end of girder above crane cab. An approved method shall be provided for locking switches in the open position. Locks will be furnished by the purchaser.

By opening either switch the control lines to circuit breakers or main switch are to be opened.

19—Wiring: Controllers and switchboards shall be mounted by purchaser who will do all wiring necessary for the proper operation of the crane.

All wiring to be in accordance with National Board of Fire Underwriters Rules, 1915. All wires on cranes unless otherwise noted, shall be flexible stranded rubber covered 30% para, fireproof finish, 600-volt insulation.

All wires shall be drawn into approved metal conduit. All outlets shall be through approved conduit fittings.

Each motor shall be wired independently of all others beyond its own switch blocks. No common return for two or more motors will be allowed.

No wires smaller than No. 6 B. & S. gauge are to be used excepting for pilot lights and circuit breaker control.

A blue-print showing complete wiring of crane to be framed, protected by glass and mounted in cage.

When use of lifting magnet is specified, cranes shall be wired complete for magnet, including line switch, controller, cable, etc. Magnet line switch shall be located on main switchboard and connected between main line switch and circuit breakers. Magnet will be furnished by purchaser.

The following sizes of wire will be allowed for motors and apply to four or less single conductors in one circuit, or to four or less conductor cables:

Size Motor 230 Volts	Approximate Amperes	Size Wire B. & S. Gauge
5	21	6
10	42	6
15	61	6
30	120	2
50	200	00
75	300	0000
100	400	300,000 c. m.
150	600	500,000 c. m.
200	800	1,000,000 c. m.

20—Collectors: No trolley wires shall be used. $\frac{1}{2}$ "x2" steel bars shall be furnished by builder, all joints as per purchasers drawing, and resting on porcelain insulators shown on accompanying drawing.

The builder shall furnish two sets of trolley collector shoes and two sets of bridge collector shoes. Collector shoes to be provided with braided copper shunts.

21—Cage: The cage shall be built of structural material. It shall be thoroughly braced to minimize vibration, to be located at one side and one end of the bridge girder.

The floor of the cage shall be constructed of 5-16" steel plate supported on angles not more than twenty-four (24) inches from center to center and shall be covered with $\frac{3}{4}$ " asbestos lumber.

A ladder is to be provided to give convenient and safe access to footwalks and bridge girders.

A foot gong shall be provided in floor of cab.

If an inside crane, cage shall be left open. If an outside crane, cage shall be weather proof, being covered with one eighth ($\frac{1}{8}$) inch steel, riveted to supporting angles. In outside cage, metallic sash

windows shall be provided on three sides of the cage, so arranged that when open, they shall drop completely out of sight behind the side of the cage to avoid breakage.

22—Gears and Gear Cases: All gears shall be of the spur type and have cut teeth of diametral pitch not less than four pitch B. & S. Standard 15 degrees involute. All pinions having a pitch diameter of not more than three (3) times the diameters of the shaft on which they are to be keyed, shall be of forged steel. All gears, pinions, wheels and couplings shall be pressed onto shaft as well as keyed. Armature shaft pinion and brake wheel shall have motor builder's standard taper fits to shaft.

No special gears can be used without the written consent of the purchaser's engineer.

There shall be no overhung or split gears on the crane.

The use of set screws shall be avoided wherever possible. Where such is unavoidable, safety set screws that do not project beyond the perimeters of hubs, collars, etc., shall be used.

Keys shall be so placed as to avoid catching clothing of operators of inspectors. If this cannot otherwise be avoided, key heads shall be suitably and substantially hooded.

All gears including master wheel on hoist and truck wheel gears on the bridge, shall be provided with tight cast steel gear cases.

All motor pinions and back axle gears shall be motor builder's standard.

23—Shafting: All parts of crane shall be readily accessible and it shall not be necessary to remove any part keyed on or disturb any other shaft in order to change any shaft on the crane.

All shafting must be of actual and not normal diameters. In other words, a six (6) inch shaft must be six (6) inches and not five and fifteen-sixteenths inches.

24—Keys: All keys shall be made of square steel equal to one-fourth of the diameter of the shaft on which they are to be used, plus one-eighth inch and shall be bedded one-half on shaft and one-half in wheel or coupling except armature shaft keyways, which shall be motor builder's standard. All keys shall be finished to standard taper and where necessary, provided with heads. Feather keys shall be used in all cases where gear or brake wheel, etc., is located between two adjacent bearings.

25—Bearings: All bearings shall be provided with cast steel caps, finished male and female, accurately machined and lined with split bronze shells so that any shafting may be removed from the crane with all its gears, pinions, etc., still in position.

All bearing shells shall be double flanged and shall be held from turning by lugs cast to top half and passing through cap. No dowel pin shall be used. The bottom half of the brasses shall be left plain. All shells shall be made of nickel bronze. All track wheel bearings shall be according to blue-print herewith.

All other bearings shall be supplied with an approved type of positive screw feed compression grease cups of a capacity of not less than 5 oz. for shafts, 3" in diameter and over, and not less than 3 oz. for shafts under 3" diameter.

26—Bolts: All bolts, except as stated below, to be rough machine bolts, United States standard thread and cold pressed hexagon nuts.

All bolts in shaft couplings to be finished machine bolts, fitted in reamed holes.

All bolts used in fastening tie pieces or motor support to side frames of trolley, bridge girders to end carriages, bridge motor and line shaft supports to girders, shall be finished machine bolts fitted in reamed holes. No stud bolts will be allowed.

27—Tools: Cranes shall be provided with a full set of jaw wrenches, socket wrenches and other tools required to fit each size of bolts or nuts used, and do work required in the ordinary repair of the crane.

A tool box made of plates, provided with hinges and padlock shall be attached to the bridge girders by the side of the footwalk.

This tool box to be five feet long, eighteen inches wide and eighteen inches high, and partitioned off at one end ten inches long for waste and twenty-four inches long for oil can.

28—Erection: The builder shall be responsible for crane until same is erected and shall furnish a competent engineer to superintend the erection and starting of the crane without extra cost to the purchaser. The purchaser will furnish all common labor, tackle, etc., required for the work.

29—Painting: All structural work, castings and shafting except wearing surfaces shall be well painted.

All parts inaccessible after assembling shall be painted before assembling.

30—Strength and Factor of Safety: In no case shall the fibre stress in cast iron exceed two thousand lbs. in tension, or eight thousand lbs. in compression. In no case shall the fibre stress in cast steel exceed eight thousand lbs. in tension or ten thousand lbs. in compression.

Different parts of crane shall conform to the following chemical analysis:

Tires and gear rims—Rolled steel, made by open hearth process, carbon .65% to .85%, manganese .55% to .80% phosphorous not over .05%, sulphur not over .05% and silicon .10% to .30%.

Shafting, axles and pinions—Forged steel, made by open hearth process, carbon .30% to .40%, manganese .35% to .45%, phosphorous not over .05%, sulphur not over .05% and silicon .15% to .30%.

All castings except drums—Steel castings made by open hearth process, carbon .30% to .40%, manganese not over .75%, phosphorous not over .04%, sulphur not over .05%, and silicon not over .35%.

Drums—Cast iron, air furnace, carbon not over 2.00%, manganese not over .8%, phosphorous not over .40%, sulphur not over .80% and silicon not over 1.00%.

All castings shall be made of best material, sound and free from blowholes, shrinkage cracks or other defects, and defective castings shall not be patched or welded without consent of purchaser's engineer.

All structural steel to conform to the Association of Iron & Steel Manufacturers' specifications for medium structural steel.

All parts of crane not hereinbefore noted shall be designed with a factor of safety of not less than five. Hoist gearing with a factor of safety not less than eight when operated to its maximum rated capacity.

31—Drawings: The bidder shall submit blue-prints showing general arrangement and construction of crane with his proposal. The builder shall furnish the purchaser with two complete sets of working drawings, including general arrangement of both trolley and bridge. Prints shall be forwarded as soon as the work in the drafting room is completed and checked. Work shall not be started in shops until drawings have been approved and one set is returned.

All details shall be subject to the approval of the purchaser's engineer. Such approval by the purchaser does not relieve the builder of responsibility of the proper working of the crane.

One set of brown positive prints of the final corrected working drawings of the crane which shall be complete in every detail and include general arrangement shall be furnished by the builder before final payment on the crane is made.

All parts of the crane shall be finished to the drawing, no part especially fitted to its place so that spare parts made to the drawing shall be interchangeable with the same parts on the crane.

32—Inspection: All work shall be subject to the approval of the purchaser's inspector, who shall have access at all times to all departments where the crane is being built and shall be afforded ample opportunity for thorough inspection.

33—Test and Acceptance: When the crane has been installed, its acceptance shall be subject to its compliance to the foregoing specifications, to be determined by an inspection and test. The test shall be made at the maximum working load of the crane as hereinafter specified. If the crane is found to comply with all the requirements of this specification, it shall be accepted at once.

34—Guarantee: The builder shall guarantee the crane to be mechanically and electrically free from defects in workmanship, material and design and shall make good by repairs or replacements any parts that shall prove defective within one year from date of acceptance of crane, without extra expense to the purchaser. The same guarantee shall apply to part repaired or replaced dating from time repair or replacement is made.

EGAN: CRANE SPECIFICATIONS

35—**Delivery:** Bidder shall state the time of delivery with his proposal. Crane to be delivered f.o.b. cars at the works of the purchaser.

36—**Specifications:** This specification shall be attached to and form a part of the builder's specifications, and in case of a conflict between the two, this specification shall take precedence and the requirements set forth herein shall be carried out.

Points not covered shall be governed by builders specifications or by what is known as good practice among crane builders.

Builders shall supply all dimensions or other data indicated in these specifications but not filled in.

It is the intention that this crane shall, when completed, be so constituted as to be nearly free from causes of accident to persons engaged on or about the crane as it is possible to make it. Builder shall provide any additional safeguards that may be necessary to accomplish this purpose.

These specifications were written with the purpose of obtaining a crane that shall be first class and safe in every respect. They are written with the desire not to embarrass any manufacturer by incorporating any requirements that would prohibit his bidding. Any clause herein that tends to work a hardship upon the bidder, may be taken up with the purchaser's engineer before price is submitted with a view of obtaining relief.

37—**Propositions:** All propositions shall state:

- 1—Total weight.
- 2—Weight of trolley.
- 3—Maximum load on each wheel
- 4—Limit of travel of hooks.
- 5—Size of motors.
- 6—Speed of motors.
- 7—Time of delivery.
- 8—Price delivered, including services of erector.

Dec. 1, 1916.

NOTE—This general specification is sent to each crane builder but once, and is kept in his files, and is to be used on all cranes as specified or excepted by individual specifications.

INDIVIDUAL SPECIFICATIONS FOR THIS CRANE

Department—
Use—
Number of Cranes—
Capacity—Main Hoist
Capacity—Auxiliary Hoist—
Span—
Maximum Lift—Main Hoist—
Maximum Lift—Auxiliary Hoist—
Main Hoist Speed—
Auxiliary Hoist Speed—
Trolley Speed—
Bridge Speed—
Section of runway rail—
Section of Trolley Rail—
Lifting Tackle—Main Hoist—
Lifting Tackle—Auxiliary Hoist—
Type of Cage—
Type of Limit Switch—
Type of Brake Solenoids—
Diameter of Bridge Truck Wheels—
Diameter of Trolley Truck Wheels—
Crane to be equipped for magnet—
Bridge Collector Drawing—
Building Clearance Drawing—
Standard Truck Axle Box—
Crane to be equipped with "A" Frame—
Collector Shoe Holder (Bridge)—
Collector Shoe Holder (Trolley)—
Collector Shoe (Bridge)—
Collector Shoe (Trolley)—
Porcelain Insulator for Collector Bars—
Standard Joint for Collector Bars—
Crane Bumpers—
Arrangement of Magnet Drum Collectors—

Our general specifications, dated Dec. 1st, 1916, shall apply on this crane, with the following exceptions:—

DISCUSSION

W. T. Snyder: Mr. Egan seems to have presented a very complete crane specification. Back in 1907, this Association prepared and adopted a crane specification, which was somewhat along the lines Mr. Egan has presented. Some time ago, that specification was declared null and void, because it had not been kept up to date; it was the sense of the directors that it should not be allowed to go out as the Association of Iron & Steel Electrical Engineers' specification and be used as a basis for specifications by the state authorities and others. It seems to me that the Association should have an up-to-date crane standard—I do not know whether to call it specification or standard, and it would seem that the specification presented would be a good basis to work from. Have our Standardization Committee go over it and modify it, and try to make out of it what could be called an Association of Iron & Steel Electrical Engineers' Crane standard. We would like to have you discuss the paper from that standpoint; manufacturers from their standpoint, and mill men from the standpoint of the user.

Eric Zachau: It is not quite clear to me, Mr. President, whether these rules as read are simply a suggestion to be discussed, boiled down and finally adopted, or whether this is the final hearing in the matter. I could say a good deal on this subject, but would like to have this question answered before proceeding. Are these rules as read proposed merely as a subject of discussion?

W. T. Snyder: That is all. We could not at this meeting adopt a crane standard. Before anything can be put out, it must come before the Association at its next annual convention or some other convention.

Eric Zachau: The drafting of a set of rules which would be applicable in all cases without working any hardship on either crane user or manufacturer and yet insure a satisfactory product in all respects would, of course, be the ideal and I am certain you would find the manufacturers only too glad to adopt such rules as standard. On the other hand, you realize that there are hardly any two cranes doing exactly the same service and it is indeed difficult to draw a

set of rules governing all cases. My idea about crane specifications to be recommended by this body of men is to draw some broad general outlines, giving the trend of your experience and general engineering practice to govern crane design. I do not believe it wise to go too much into detail, because by so doing you are defeating your own cause in that you reduce the adaptability of the rules. There are in the specifications as read a number of features which could and should be adopted as standard while on other points I believe the specifications go too far. As long as the discussion is free, I will call attention to a few features that I have made note of, not so much with an idea of starting an argument on the different points, for which the time is entirely too short, but rather to support my contention that it is unwise to go too much into detail.

You specify cast steel end trucks. That is rather an arbitrary rule, since the relative merits of cast or structural steel end trucks are open to argument. In general, I believe it unwise to specify material to be employed where there is the least difference of opinion, since after all it is largely a matter of design and often one material may be as good as the next if the parts are properly proportioned.

You specify maximum wheel load and minimum wheel base, both of which features are largely dependent on building construction and therefore cannot properly be covered by crane specifications.

To specify dynamic braking is another instance of going too far into detail and this rule does not apply to a large class of cranes, namely alternating-current cranes.

Two magnetic brakes with dynamic braking is another questionable advantage. It is a safety feature in a way and in another it is not. With two brake coils in series with the motor fields a circuit of considerable self induction is established which will result in sluggish operation of the brakes. This way the motor will start or try to start with the brakes applied and again when the current is shut off, the brakes will not set quickly, thus permitting excessive drift of the load. It is therefore open to question whether one extra powerful brake will not prove more satisfactory from all viewpoints and at any rate it is a matter of design rather than safety.

In specifying by whom the motors shall be purchased, terms of payment, etc., Mr. Egan is covering a field which is entirely foreign to engineering specifications to be suggested by this Association.

These are merely a few points and I repeat that I had no notice that this subject would come up for discussion or I would probably have more to say since it naturally is a subject close to my own heart. I believe, however, that we can serve both sides and the aims of this Association to better advantage by drafting specifications which will cover the general design of the crane without going into detail too much, which might necessitate an elaborate classification of cranes to not work hardship on the crane user. As I said before, were it possible to draft a set of specifications which could be applied universally we crane builders would be only too glad to fall in line, but inasmuch as this is impossible we should aim our rules to simply point the way towards a better design and construction of cranes, and I feel safe in assuring you of the hearty co-operation from the crane builders towards this end.

W. T. Snyder: I think Mr. Zachau is entirely right in the points he has made; that this Association cannot go on record as recommending any considerable number of the detail recommendations that are contained in this specification; and for that matter, any recommendation the Association would make would not be binding on the purchaser or crane manufacturer, but rather a guide for the other members of the Association, wherein they may benefit by the experience of some members who have more experience with operating and buying cranes, and we hope you will not discuss this specification altogether from the same standpoint as Mr. Zachau. We hope you will pick out some of the details, both crane manufacturers and mill men, as though you were criticizing Mr. Egan's specifications and not the Association specifications.

S. C. Coey: I remember my father used to say, unless you break a rule now and then, you won't know you have any rules, but he generally used to accompany that with some chastisement. Now, I happened to be a member of the Ohio committee that was appointed by the Industrial Commission to draw up rules for the safeguarding of cranes

in industrial plants. Now most of us have crane specifications that we send out when we buy cranes, and on practically every crane you buy, there are certain exceptions in the specifications. The National Safety Council got out a careful set of specifications drawn up in a manner similar to which these were drawn up, and when this Committee met at Columbus, the chairman had a copy of these tentative rules for the construction of cranes and seemed to think that they would be a good thing to adopt as law for cranes in the state of Ohio. The point I want to bring out is that if we adopted those rules in Ohio, nearly every crane in every plant in that state would have something about it that would not conform to the rules as outlined, and it is very important in making up a set of specifications that will go out under the name of this Association, that they bear in mind that very point, because the specifications will get to these industrial commissions and be made fixed rules for governing the industries. It is up to us to see that they don't make foolish laws which it is impossible to live up to in all cases.

In regard to Mr. Egan's specifications, Mr. Zachau does not believe in cast steel end trucks; he thinks structural is better. That is one point which is merely a matter of experience, and, perhaps, personal opinion. I firmly believe that cast steel end truck is better than structural end truck. I believe Mr. Parkhurst would take the other side very decidedly. But when Mr. Egan uses the cast steel end truck on bridge and trolley, I cannot understand for the life of me why he uses structural motor support for his bridge, because I know we have had more trouble with structural bridge supports than we have with structural end trucks, and we find the cast steel bridge motor support is of greater value, if anything, than cast steel end trucks.

I notice that in the first specification, Mr. Egan states that the crane shall be known as an "all-steel crane", and then later he calls for air furnace iron in drums; that is a little exception to an "all-steel crane". I believe air furnace iron is right for drums. He specifies that the gears shall be spur gears. I think it would be very foolish for the Association to make any such specification, at the present time it is impossible to get sufficient cutters for helical gears and

equip our cranes with them entirely. I know in our case, on an ore bridge, we had a lot of trouble with the gearing on the hoist and trolley, and finally put on helical gears on this bridge, and eliminated about half the trouble with armatures on that ore bridge by the use of helical gears. I know another plant with some cranes entirely equipped with helical gears, and they are the most quiet running cranes I have ever seen. It looks as though they will show improvement over the spur gear. With spur gear, there is a certain amount of back lash, a hammering action there that you get away from by the use of helical gears. I think it would be foolish to include a specification which in the course of a few years might be found to be entirely wrong.

I notice that Mr. Egan specifies that all lifting cables shall be 6-strand, 37 wire plow steel. I have found on counterweighted cranes that a lang-laid steel rope will outlast a standard steel rope, sometimes as high as 4 to 1, due to the fact that with that lang-laid rope there is no action due to the wires crossing one another as in the case in the ordinary steel cable. It is impossible to use lang-laid rope unless you counterweight, because the cable jumps off the sheaves; but where it is a counterweight proposition, the lang-laid will stay straight and will outlast the other type of rope.

W. C. Minier: Mr. Zachau has expressed my convictions perhaps better than I could myself. It seems to me that specifications coming from the Association should be rather broad as regards both design and material, and the user could be privileged to incorporate any special equipment to suit his own needs, or his opinion of different types.

W. T. Snyder: I think that it is generally understood that anything the Association puts out will have to be of a general nature; so I do not think we need put in any more time on that subject. We would like to have different features of design discussed. We would like to know from Mr. Egan why cast steel end trucks are better than structural; and from Mr. Zachau why the structural is better?

E. Friedlaender: This subject has been discussed at various times by our Association. The all-steel modern mill-type electric traveling crane is practically a product of our members. As mentioned by Mr. Coey, the various

states have drawn up general rules for the construction and safe operation of cranes; I was present at several meetings of the Pennsylvania committee appointed by the Industrial Commission, when such specifications were discussed. Since then the specifications have been adopted by the State of Pennsylvania and have become a law. These rules are very broad and cover most of the points our Association has brought up in the past.

The American Society of Mechanical Engineers has recently discussed those rules in New York, and has adopted them substantially as drawn up. I think our Association should do the same and not go too much in detail. Whether we specify steel structure or castings, whether angle-iron or pipe is used, spur gears or helical, etc., should be left to the discretion of the purchaser.

Referring to Mr. Zachau's remarks about brakes, I do not like to see electric brakes set too quickly, as it puts very severe stresses on shafts and bearing caps.

W. T. Snyder: In regard to Mr. Friedlaender's remarks that the Association could not recommend angle iron or pipe rail, I quite agree with him on that point. Neither the Association nor the Committee should recommend what the railing should be made of; but I see no objection to the Committee or the Association recommending that a steel railing be provided of a certain height, but make it of whatever section they desire.

R. H. McLain: I wish to make a few remarks regarding the details brought out in Mr. Egan's paper.

When dynamic braking control is used on the hoist motion, I believe it is advisable, in a good many cases, to have two solenoid brakes instead of one. Such a practice represents in a measure the former practice with cranes of having one mechanical load brake and one solenoid brake. If the dynamic braking goes out of commission, you have two friction brakes left. It seems to me that when two solenoid brakes are used, ample safety will be obtained by having each brake capable of stopping 120% of full load. Too much braking torque is a disadvantage because of shocks on the machinery. Too little braking torque will, of course, be dangerous. I think it is advisable to have a brake of the band type on the jack shaft so as not to get high torque

from this brake when the load is being stopped in the hoisting direction but get full torque when stopping in the lowering direction. The brake, which is mounted on the motor shaft, should be of the shoe type so as to prevent too much coasting in the hoisting direction and to get the other benefits which come from the reliable clearance of a shoe type brake when used on a high speed shaft.

I have seen quite a lot of trouble arise from the use of gravity set solenoid brakes when the core of the solenoid was allowed to drop freely. The free drop of the core produces, at the moment when the core strikes bottom, an extremely high braking torque—in some instances ten times normal—which sends a severe shock throughout the train of machinery connecting the brake with the load. In my opinion there should be a dash pot connected to the solenoid core which has sufficient time element to eliminate the extra hammer-blow pressure which comes from the falling core.

In regard to dynamic brake specifications, if I heard Mr. Egan correctly, he specified that a light hook should not be lowered at 200% of normal speed and a loaded hook should not be lowered at over 100% of normal speed. It seems to me that you should lower a load as fast as possible under all circumstances unless the particular material which you are handling demands a slow speed. If the motor and gearing will stand to run at 200% of normal hoisting speed under no load, there is such a slight extra strain produced by lowering the full load that there should be no disadvantage whatsoever in lowering a full load at 200% of normal speed. Such a practice will gain time in the operation of the crane. Of course a controller should have slow speed points which can be used for landing the load. There is no danger of lowering a slab of rough material at 50 or 100 feet per minute no matter what the hoisting speed might have been. On the other hand, it might be advisable with some hot metal ladle cranes to limit the lowering speed for safety's sake. I believe there is a fallacy in attempting to make a motor lower a load with the same characteristics that it hoists a load—that is hoist a heavy load slowly and a light load fast under all conditions. The advantage of hoisting a heavy load slowly is that it saves power input into the crane and saves in the motor size. Ordinarily

there is no other reason why a load should not be hoisted much more rapidly than is the usual practice—provided, of course, that sufficient slow speed points are provided on the controller to enable an operator to handle his load conveniently.

Another feature which dynamic braking control should have is that of bringing the load to practically a dead standstill before the solenoid brake is allowed to set. This relieves machinery of the shock which is bound to come from a powerful solenoid brake, and also relieves solenoid brake of a great deal of wear, thereby leaving it in good operating condition for emergencies. The extra work which stopping the load puts on a motor is imperceptible.

Mr. Egan's list of specifications, of course, made no reference of methods of choosing the proper size of motor to go on a crane; but I believe that it would be a good thing for this organization to get out some kind of written rules in regard to the selection of motor sizes for cranes. The rules should be based on good practical experience as well as mechanical formulas. Such a set of rules would serve as an excellent guide for a young man who is starting in to lay out cranes, and would materially assist everyone by serving as a check.

A set of rules or specifications in regard to the location of grids and other control apparatus which is likely to be affected by the vibration of the crane should prove very valuable. I have seen cases where grids were so located as to produce a vibration similar to that in a tuning fork which rapidly crystalizes the grids. The only effective remedy was to change the location of the grids.

I think that Mr. Coey's remarks about the use of helical gears are very timely, especially on high speed gearing and very busy cranes. This kind of gearing saves a lot in friction losses, eliminates a lot of noise and saves a lot in motor repairs. I know of a case where a coal bridge, in a small town, was equipped with spur gears. The spur gears proved such a noise nuisance that the town passed a law prohibiting their use. Helical gears entirely relieved the situation.

C. A. Menk: I feel a little like Mr. Friedlaender; it seems as though the state has taken out of the hands of the

Association what they should provide in the shape of crane specifications, and now that they have done that, it looks as if it is going to be a game of detail. It seems as though this Association should recommend such detail that would bring up the crane and make it a modern specification, and in that way would get the very best possible. We are not going to accomplish a great deal if everyone works on his own foundation. We will have to combine and get ideas from all the members and users of cranes, which will give us the very best results.

I notice one thing that has never been dwelt on, that is, the question of making a crane safe in the way of eliminating bolts. Standard crane shipped out from the manufacturing plant provided with hand rail, foot walk, and even fastening of girders on to end trucks are bolted. I think that is a great mistake. The last four or five years we have endeavored to rivet up everything we possibly could on a crane, and we can see today where that has more than justified going to that extra expense, because you all know where you bolt anything up, it is only a question of time until it loosens up. I think that is quite an important item. I do not think there has ever been very much said on that one particular feature of a crane specification.

We adopted crane specifications a few years ago and have lived up to them just as near as we possibly could, and I believe in doing that we have helped the builders in a great many ways and others who have bought cranes. We know it has been a good thing for us, because it eliminated certain things we had to contend with in the old style of crane, and I believe it more than justified us in drawing up our specifications.

W. T. Snyder: It occurs to me that Mr. Friedlaender's remarks has given the wrong impression. I hardly believe the state is going to pass a law to tell you how to build a crane. What they are trying to do is to take care of the safety features and safe operation of the cranes. I believe that is as far as the state will go; beyond that, the state has no business bothering with it.

Mr. Egan says: "the girders forming the bridge shall be 'Builder's Standard Design' box girders." Will he tell

us why he would rather have box girder than built-up girder?

F. J. Brittingham: The object of this Society should be to take care of safety features, and not tell whether cast steel end trucks or built up end trucks are preferable. The conditions may be such that a cast steel end truck need not be used, and there may be cases where it would be better. The question of brakes is more a question of each man's own idea. The crane builder can arrange brakes in almost any way he wants. I believe that a general specification should be drawn up and simply have safety features covered, and if a particular design is required, get the crane builder to figure that way. If he wants to take any exceptions, let him do so.

W. T. Snyder: I do not quite agree with Mr. Brittingham, on that brake question. Just taking that one point singly. I might specify what kind of brake I would like to have, and the brake I would specify, might be, in my judgment, the best. On the other hand if the committee of this Association had canvassed the members of this Association and got recommendations on a brake, when I come to specify the brake, and I find the brake this Association recommends is different altogether to the one I had in mind, it would at least set me to thinking and investigating the other brake. If I found I was wrong, the recommendation would have done that much good. It is not as likely that recommendation would be wrong as it would be likely that I would be wrong in my own individual judgment.

S. S. Wales: I haven't a great deal to say in the way of criticism, but something in defense of the specifications read tonight. I cannot recall the dates but I remember the circumstances under which a great many of the steps were made. There are several representatives of crane builders here tonight but only one that I know of who was in the game when a crane consisted only of two end trucks, two girders, a railway motor and a skeleton trolley with two motors hung onto it in some fashion or other.

It was hard to change a bridge motor and armature when we had to hang on to a greasy rail with one hand, with one foot on the bottom angle of the girder, so we asked for foot walks. After we had slipped and fallen off of the foot

walks, we put hand rails around them. We had structural end trucks that had only one wheel in line at a time so we made them out of cast steel. We had cast iron frames which broke, so we made them out of steel. We had many cranes with no two motors of the same type, so we began to dictate the motors to be used. We had wooden cabs that burned up periodically when sufficiently soaked with oil. We had bearings on shafts that were babbitted and when the babbitt wore out we had to rebabbit them, sometimes in zero weather, so we asked to have brass sleeves furnished. Then we squirted most of the grease between the cap and the brass sleeve so that little of it got on the shaft, so we brought the boss out through the cap and put the grease through it. After hammering pins out of end truck wheels through the end trucks and breaking them, we put on the railway bearing box. So I could go through many more of the details he has specified.

I do not believe in putting in quite so many limits if this is to be a general specification, but I understand it was made up to suit his particular purpose and simply submitted here as a possible guide or basis for discussion. As to the main features, I will say that there were many cases when it became absolutely necessary in order to continue operations, to make these modifications, and regardless of what the state does for steel mill use, they are nearly all good. In going into the market for cranes for machine shop use, we can throw our special specifications away but when we need a crane that must operate seven days and seven nights a week, I think most of the requirements stated will enable our engineers to sleep better at night.

W. T. Snyder: The specification reads, "the drum gear bore shall not be less than 80% of the diameter of the drum." I would like to ask the reason for this, or whether it is just arbitrary?

Is it better to have a few large cables or a number of small cables on large hot metal cranes.

Eric Zachau: One more point: motor sizes. The horsepower rating of a motor does not mean anything unless the basis of rating is specified. There is one thing this body might well go on record for and that is a uniform basis of motor rating. We have today almost as many rat-

ings as we have motor manufacturers and that is an unfortunate condition. A 50 h.p. motor of one make may not have the capacity of a 40-h.p. of another. We have ratings based on 40, 55 and 75 degrees heating for periods ranging from 20 minutes to one hour. We have one minute on and one minute off ratings and others. Here, to my mind, is one of the most important points for standardization.

R. H. McLain: The American Institute of Electrical Engineers has gotten up quite a complete set of rules in regard to ratings of motors, and I think it would be mighty well to join with that body on that point. They are making their rules to apply to steel mills as well as anything else. They are uniform rules and one set should be about as good as another.

E. Friedlaender: I do not quite agree with Mr. Zachau on the question of buying motors. In order to reduce the number of spares, we not only specify the horsepower of motors, but actually state what type and make of motor to use. In doing this, our plant succeeded in acquiring but a few different sizes of motors on the last fifty cranes purchased. Motors seem to be large for the speeds specified, but especially on bridge and trolley drives we must consider the abuse the motors are subjected to.

When I said I would like to see State rules adopted, I did not mean that we should not discuss details. On the contrary, I would like to have details thoroughly discussed, but would not favor our Association printing them as standards unless we can say that no further developments are possible in crane design and construction. I hardly think we are ready to say this—far from it. I hope crane builders will keep on making improvements and not be satisfied with the crane of today.

B. R. Shover: The majority of electricians have had experience with worn-out brake apparatus and burned-out motors caused by the difficulty of keeping brake mechanism concentric with the armature when motor and brake are mounted separately, therefore it would be interesting and instructive to learn how Mr. Egan has overcome this difficulty.

The use of rivets instead of bolts brought out by Mr. Menk is to be recommended. One plant which had high maintenance costs on its cranes replaced practically all bolts

except those in bearing caps by rivets, with the result that the inspection force was reduced 50% and the time lost for inspection and repairs cut down even more.

Meeting the troubles of earlier days, described by Mr. Wales, by improvements such as are required in the specifications under discussion has resulted in a far safer and more reliable piece of machinery, but has at the same given a crane of excessive weight, necessitating heavier buildings and requiring more power for doing the same work. Many modern cranes are greatly overmotored, and as the larger motor increases the effect of careless operation, shafts, gears, etc., have been made larger, the total increase in weight being carried on heavier girders. Practically no attempt seems to have been made towards using the minimum size motor which would give satisfactory service or to get any additional strength required for shafts, gears, girders, etc., by changes in design, better workmanship or the use of materials such as alloy steels, or towards minimizing the effect of careless operation by the use of automatic control except on large motors.

In the plant of the Tata Iron & Steel Co., at Sakchi, India are some German cranes which probably do not have over two thirds the weight of our modern "all steel" type. In these cranes material is used to the very best advantage, the workmanship is superior to that on American cranes, and the motors are considerably smaller than those used for similar service here. They are operated and repaired entirely by Indian labor which is neither as experienced nor efficient as labor here, yet in spite of the lightness of the crane and the character of the labor, their reliability and maintenance will compare favorably with those items for our most modern cranes doing similar duty.

An interesting, as well as profitable, experiment could be made with two old (and consequently light) cranes doing the same work, by equipping one with the best obtainable automatic magnetic, the other with ordinary hand-operated controllers and then keeping accurate records over a considerable period of the repairs and lost time of both. The results would not only determine the relative value of the two methods of control, but might also give a basis on which to figure a crane lighter than the modern type which would

also give equal satisfaction with regard to safety, reliability and maintenance.

It appears than in the endeavor to eliminate shut-downs, increased size of parts only has been considered while the better use of material and the use of better material and workmanship have been largely neglected, nor would it be surprising if someone, in the not distant future, would be courageous enough to build a crane along the lines which have made the automobile such a success, that is obtain strength and reliability by the use of better designs, using the most suitable material in the most efficient manner, coupled with much better workmanship than is now considered necessary.

E. J. Schwarznau: Our specifications, in general, conform very much with Mr. Egan's recommendations, except that we incorporate the size and make of motor to be used; for the crane builder's information.

Regarding the size of brakes, we specify 150% of the torque of the motor. We have recently adopted shoe brakes, as we find, from tests we have made, that they give entire satisfaction.

Regarding end trucks, I find that at one of our plants, where we have very capable men in charge, they prefer the steel end truck. The reason for this is that they prefer the pin type bearing over the M.C.B. bearing. However, I believe that is merely a matter of opinion with them. My observation has been that cast steel end trucks cost more than structural steel end trucks.

Regarding safety ropes for ladle cranes, I believe we cannot do enough in the interest of safety on this type of crane.

I can readily see why crane manufacturers would object to adopting a standard specification prepared by this Society as it would then be only a question of price with them. I find there is a great variation in the designs of the different cranes, and, although their standard commercial cranes can be used for light work such as machine shop and warehouse service, or other places of light requirements, yet for hot mills, annealing departments and other places requiring heavy service, and where the operation of the plant depends

entirely upon the crane, we recommend the mill type crane regardless of cost.

I believe that recommendations from a Society like this would be of great value to any concern when purchasing cranes, as there were a few points mentioned here tonight in which I am very much interested; particularly that of helical gears, as I believe they will be universally adopted for this class of work. We have made tests on heat-treated gears and find that they are very satisfactory. I find that the cost of gears, and the life of these gears is guaranteed by the manufacturers to be four times the life of the ordinary gear. From this, you can readily appreciate that if the heat-treated gear costs only 20% more and will last four times as long as the ordinary gear, it is certainly a good investment.

A. W. Duncan: I do not know whether I can add anything to what has been said along this line, but I have had considerable experience with cranes, and had to smile to myself when Mr. Wales was talking here tonight, because I have passed through some similar experiences myself; and I feel just as he does, that in some way there has been wonderful strides made in the building and designing of cranes in the last few years. Since I have been here, I believe I see where some of it has come from.

In regard to crane specifications, would say I wouldn't think it possible for a body of this kind to specify any method of building cranes which could be adopted for all service, because there are so many classes of crane service and different methods of using cranes. It would be almost an impossibility.

I haven't heard tonight any discussion at all regarding alternating-current driven cranes, and I would be interested in hearing something along that line.

W. T. Snyder: I would like to ask if there isn't a field for variable-speed motor on cranes, where the loads handled are of variable weights; for instance, a machine shop crane, where part of the time the crane is working on light load, and another part on heavy load; wouldn't a variable speed motor permit getting away from auxiliary hoist?

Mr. Egan specifies that grease cups be used except on M.C.B. bearings. I believe, also, there are places where

self-oiling bearings could be used. In my opinion there should be spring action between the wheel body and truck.

J. H. Albrecht: I have had quite a good deal of experience in designing brake magnets and it has always been our aim to get a snappy acting brake magnet. Mr. Friedlaender tonight has mentioned a preference for a slow acting brake magnet which is the first time I have heard that such a magnet was preferable. With the solenoid magnets as used on most of the modern brakes a slow acting magnet is very easy to obtain. By means of a solid copper band which serves as a short circuited turn or damping coil on the solenoid plunger, we can easily slow up the magnet or increase the time which it will require in opening.

R. H. McLain: I would like to take the other side of that argument. It is very desirable to have a brake pick up quickly, so you get started quickly. When the magnet is picking up quickly, it certainly puts no shock on the crane machinery. The shock is all on the magnet itself, and various ways, such as floating top core, have been devised for taking care of it. By using a dash-pot, you get the benefit of the magnet's setting gently and at the same time picking up lively. I advocate a dash-pot which has very little dash-pot action—just enough for taking the hammer blow off and nothing else, because anything else it takes off will delay the dropping of the brake, which causes loss in time and causes some coasting. It is a question of one-tenth of a second rather than one-half of a second. A dash-pot of a given size is, of course, more dependable when built with large ports for small time intervals than when built with small ports for long intervals.

John Cooper: I agree with Mr. Egan that we ought to have two brakes on the hoist. One on the armature shaft and one on the back shaft, unless I misunderstood his paper. He states the brake on the bridge drive must be on the armature shaft. I would like to know why he wants it there, instead of on the line shaft?

F. J. Burd: I would like to hear an expression of opinion on protective electrical apparatus for cranes with a view of possibly bringing out some standard combinations. For instance, when manually-operated controllers are used, a crane switchboard may be employed, mounting an overload

relay for each circuit on the crane, a main knife switch, a contactor break in each main line, a main overload relay and a safety lockout plug. Also in a great many instances it is very desirable to enclose and lock the crane switchboard in addition to covering the other electrical apparatus in the cab.

I believe the Association can do very desirable work by working up a set of suggested standards relating to control and electrical protective apparatus for cranes. These standards could be extended to cover the usual line of cranes employed in steel mills with reference to capacities, speeds, locations, etc.

E. Friedlaender: There is another point I would like to call attention to, namely, the question of safety ropes on hot metal cranes. We are specifying hoisting ropes amply large but we should not overlook the fact that both sets of ropes are wearing out together. Ropes should be so arranged that load is lifted with one set, leaving the other set practically new for emergency; we are then replacing one set at a time and always have one good set on a crane.

With further reference to electric brakes, I would prefer having them release very quickly but not set too quickly, especially where several motors are geared together and working in parallel. Should one motor stop ahead of another, the gearing, shafts and bearings will be subjected to severe stresses, especially where powerful electric shoe-type brakes and dynamic braking are employed. It is practically impossible to have mechanical and electrical breaking so adjusted that all motors will stop exactly at the same instant. By the use of dynamic braking, motion is stopped before brake sets and there is little danger of load dropping, even with a slow acting electric brake.

J. H. Albrecht: I would like to state that a damping coil or short circuited turn such as I previously mentioned, would not materially change the pickup of the brake magnet. In fact, the writer has oscillograph tests to prove that the difference in time will not be noticeable. This is due to the fact that on open gap the flux density in the solenoid core is at a very low value; consequently the inductive effect of the short-circuited current is very slight. However, when the magnet core has sealed the flux density is very high,

usually about 100,000 lines per square inch, and when the brake magnet core attempts to release from the pole face the inductive effect is very great and materially slows down the time of opening. This is the effect that I believe Mr. Friedlaender wishes to obtain. I do not agree with Mr. McLain that the damage to the crane mechanism is due to the hammer blow. This may be true with the gravity type of solenoid brake but it certainly is not true of modern spring type brakes. As I understand Mr. Friedlaender's remarks, he merely wishes to delay the action of the brake until the dynamic brake has practically brought the crane drum to rest. This effect certainly can be obtained by means of a damping coil or short-circuited turn on the solenoid magnet.

R. H. McLain: When the brake is released and the solenoid core is up you have a closed magnetic circuit. The short-circuiting strip which has been described will, under this condition, prevent the core from quickly starting to fall, but, once it starts, the magnetic circuit is then opened and the damping action practically disappears. The core can drop as freely after once starting when provided with damping coils as when not provided with damping coils. Consequently, the objectionable hammer blow of the falling core is not eliminated by the damping coil and a useless waste of time is introduced. Now, if a dash-pot is used, it does not prevent the core from starting to fall but does retard the fall of the core, thus relieving the hammer blow. To illustrate, let us assume a brake in which the down stroke of the solenoid core is two inches. If damping coils are used, the damping action will be very effective throughout the first one-eighth of an inch of the fall but during the last one and seven-eighth inches it will be practically ineffective, thus allowing the hammer blow. Whereas, if a dash-pot is used it will retard the falling of the core throughout the entire two inches and will eliminate the hammer blow.

F. B. Crosby: My remarks will be somewhat in nature of an announcement. The possibilities of standardization of steel-mill practice in electrical matters has been of great personal interest to me for a number of years. After receiving official notification of this meeting I learned of a

movement instigated by prominent representatives of several of the larger engineering associations in this country.

Through the efforts of these societies a vast amount of technical data has been compiled. Much of this data is of value to members of more than one society as evidenced by the over-lapping efforts of their several standardization committees.

Recognizing the great loss of time and energy resulting from lack of co-operation and adequate means of disseminating the data at hand, Mr. P. Junkersfeld of the Chicago Commonwealth Edison Co., arranged for an informal meeting of representatives of several Engineering Associations. Through the courtesy of a mutual acquaintance and by virtue of my membership on the Standardization Committee of this Association I was privileged to be present at the meeting held Friday, Dec. 15, 1916 in the Engineering Societies Building, New York.

The following Associations were represented at this meeting:

- American Electric Railway Engineering Association.
- American Institute of Electrical Engineers.
- Association of Edison Illuminating Engineers.
- National Electric Light Association.
- Electric Power Club.

Also unofficially represented:

- American Society of Mechanical Engineers.
- Association of Iron & Steel Electrical Engineers.

Mr. Junkersfeld was unanimously elected chairman of the meeting which then named itself a "Conference Committee of Co-operation on Technical Subjects". The scope of the Committee was defined as follows:

"The object of the Committee is to eliminate so far as possible the unnecessary duplication of technical work by various associations."

Briefly the following recommendations were drawn up for consideration of the several associations represented:

- a. Provision for joint representation between the technical committees of the several associations when working on the same, or related, subjects.
- b. Mutual assistance volunteered where feasible.

- c. Appointment of Technical Committees in Associations not already provided with same.
- d. Provision for rendering accessible to membership of interested Associations the findings of these joint committees.

If these tentative plans for organization of a permanent committee meet with approval, this committee may ultimately become one of the lesser working units of a National Engineering Standards Committee similar in its scope to the very successful Engineering Standards Committee which has made substantial growth during the past nine years in England.

The recommendations of the self-appointed Committee which met in New York the 15th will be formally presented to your Secretary at an early date.

Personally I believe it will be greatly to the advantage of this Association to identify itself with this important movement toward closer co-operation in standardization of electrical practice and equipment.

F. D. Egan: There are quite a number of questions to take up, which I will endeavor to reply to as they come.

Evidently the impression was received during the reading of the paper, that it was offered as standard of the Association. The specification was not meant in that way, although the announcement card might imply that. It is a specification as used by the Pittsburgh Crucible Steel Co., and I was not offering it in any way as a standard of the Association, but simply as a basis for discussion or argument.

In a general way, there was a good deal of criticism on going into detail. Companies which have been buying a number of cranes and those who have had experience on checking drawings and have had a number of cranes built, you will always find have a detail specification, and they try to adhere to it. In most cases they ask to have drawings submitted for approval. If you don't have detail specifications, you might as well tell the builder you want a crane, for you will get what he desires to give you, unless you have specifications. I know this from experience on a number of cranes that were purchased, and I guess everybody who has bought cranes has had the same experience.

Mr. Zachau asked why we preferred cast steel end trucks to structural trucks. It might be personal experi-

ence. My experience on structural truck on heavy mill duty, where the runways get out of alignment, I have always felt the cast steel end truck gave better satisfaction and kept operating more continuously than structural trucks.

There is also a question about dimensions of crane. The only question in reference to clearance, other than asking the builder to supply information as to purchase, etc., was that the walk opposite the line shaft be 6'-6" below the bottom chord in the building. With a clearance of 5' from the bottom chord, a man is liable to have his head come in contact with the bottom chord.

Why two motors are specified on ladle cranes? Originally with one motor, if you broke a gear on the drive, you dropped the load. The company that built that crane is now equipping them with two motors, so that breaking a gear or shaft will not allow the load to drop. Where size of motors are considered, each motor should be capable of handling full load.

In regard to brown positive prints, in our general specification, we state "that a set of brown positive prints with all details shall be supplied before final payment is made." It is my experience with engineering firms or crane builders that if you go ahead and make the final payment, you won't get your brown positive prints. If you hold up the money, you will be able to get the accounting department after the drawing room, with the result that the brown prints will come forward on time.

Mr. Coey's question, why structural bridge motor brackets and not cast steel? We haven't had any trouble with structural supports; we use possibly 50. We originally had some trouble with the motor supports where they were bolted to the girders but after reaming the holes, we experienced no further trouble. On the trolleys, we use wherever possible, cast steel motor support.

Mr. Shover brought up the question, why brake solenoid should be supported on separate base. We were using band brake with independent solenoid and followed the construction of the crane builder, using cast steel motor support and mounting the solenoid on this casting. Should we use another type of brake, we might change this arrange-

ment. We can except a point in our specification without changing our general specification.

On the question of drum, we specify cast steel or air furnace iron.

On the question of spur gearing, Mr. Coey stated on account of his experience on ore bridges, he is using helical gears. This is not an ore bridge specification. On ore bridges, skip hoist or mill drive, we specify herringbone gears.

As regards our specification, we have never felt in writing our crane specification that it had reached ultimate perfection; we revise it, possibly, every six months or a year. The original specification which we drew up when our company was organized in 1911 has been revised a number of times, and we will continue to revise it. Whenever a crane builder or any company suggests what we consider a good point, we revise our specification and take advantage of the change. A clause in here was taken from the Carnegie Steel Co. specification, and the basis of this specification goes back to the 1907 specification of the Association of Iron & Steel Electrical Engineers.

Lang-laid ropes: It is rather a small matter in a general specification. We have a number of counterweighted cranes, pit cranes and strippers, and have experienced no trouble with standard ropes. My experience has been that it is not a question of lang-laid, 6 strand, 37 plow steel ropes, or crucible steel ropes; it is more a question of securing any kind of rope. Where we specify 3 strand 37 wire, we would not hold up a crane on that account at the present time, if it is not obtainable.

In answer to Mr. Minier's question, this specification is not meant to come from the Association.

Mr. Friedlaender stated at first, he did not think we should have a standard specification of the Association; that we possibly could use the specification as laid down by the State Association. In general, the state specification does not go into detail, but I feel the specification of the Carnegie Steel Co. covers everything that is covered by Pennsylvania State Specification. As has been stated, material for the specification as laid down by the State of Pennsylvania has been taken from the Association specification.

Also the question of detail: If anyone would examine the Carnegie Steel specification, they would find it very much in detail.

The design of the girder has been brought up. We state "that the girders forming the bridge shall be builder's standard design box girders and that the top cover plates of girders shall be suitably supported to prevent bending under the trolley load." It is the top cover plate we object to bending and not the girder proper.

In reference to the question of wheel loads and bearing pressures, we state, "maximum wheel loads for two wheel trucks shall not be over 60,000 lbs. Pressure of the bridge truck wheel journals shall not exceed 750 lbs. per sq. in." The bearing pressure can be changed by changing the length of the bearing; allowing the wheel load to remain the same. 750 lbs. per sq. in. projected area of the track wheel pin.

A number of speakers brought up the question of brakes and the setting of brakes. We are operating a crane, and are using the old style band brake, a style which has objections when used on an ordinary crane, due to the fact that when hoisting, it will not hold the load, yet when used on the new style ladle crane, this objection has, in my mind, proven an advantage. We have been running about eight months with this design and haven't changed a bolt on the hoist machine.

Mr. McLain brought up the question of two brakes. Another fallacy we run into in considering the work that a ladle crane does, we always hear a majority speak of the lowering of hot metal. If you will notice the cycle in the different open hearths, not once in a hundred times, do you lower the ladles. It is always hoisted and then poured.

Mr. McLain brought up the question, whether there was not some method of calculating the size of motors. There was a paper presented by Mr. Wales before the Engineers' Society of Western Pennsylvania about twelve years ago discussing that subject. Those formulas you will find in almost any hand-book.

Mr. Snyder's question, why box girders and not structural? That might be based on personal experience. Where you have a crane operating at high speed and being reversed rapidly, the box girder type is more rigid and

a greater speed can be obtained on the bridge with the box type than with the built up type of girder.

Mr. Snyder also asked why 80% was used in design of drum bore. Some of the old type cranes had the drum between two journals with the gear overhung; the shaft in some cases would be about 4-1/2" in diameter, with this arrangement the pressure on the key would be higher than a case where the diameter of the gear was greater, the pressure on the key will be inversely proportional to the increase in gear diameter.

Answering the following questions: First, why cast steel gear cases? Second, why feather keys between bearings? Third, the use of iron caps as a standard construction? My experience has been that cast iron gear casings break in changing and cases made of boiler plate generally got out of shape, and for that reason, we decided to use cast steel gear cases. Where we specify "feather keys shall be used in all cases where gears, brake wheels, etc., are located between two adjacent bearings"; this is specified due to the fact that if the keys are not of a feather type that they will work out of the case and cut the face of the adjacent brasses. The cranes originally furnished by the Morgan Engineering Co. had cast iron caps and in a great number of cases, after breaking, these have been replaced by cast steel caps. In using dynamic braking, it was a question with us whether or not we would have occasion to go back and use the old style load brake. We had our original cranes designed with this in view but so far have been very thankful to feel that we have never had occasion to install another load brake. On our later designed cranes, we made no provision to allow for the installing of a load brake.

The question has been brought up a number of times this evening in reference to whether it would be advisable to use safety ropes or not. From personal experience, in operating a ladle crane, after seeing a number of accidents, I would feel that it would be criminal, as well as not safe, to install a ladle crane that was handling any sort of hot metal without using safety ropes.

Mr. Wales spoke in a rather humorous way of the causes of the development of the present style design of crane, in which he outlined the reason for a number of the changes

that we have since adopted as standard crane practice. Wish to say that while Mr. Wales was superintendent of the electrical department at Homestead, during the development of the change in the specifications, I occupied one of the lower positions in his organization. I might say that I was one of the men that got down on the girders to change shafts and in fact was one of the men he refers to as falling off the crane, due to no safety platform; and, from that time I have been a great advocate of safety. In operating ladle cranes in those days, we used to say a prayer before pouring a heat, trusting that it would be carried out successful without the dropping of the ladle, and in case of an accident there was little show for the operator as it was impossible to get out of the cage and no safety platforms or walks were provided for his escape. There was an attempt made to get around this point by installing cabs on both ends of the ladle cranes. This was needed in the older mills due to the arrangement of the open hearth building having parallel rows of furnaces. Ladles would have to be lifted at both ends of the cranes.

I also did some of the babbitting in zero weather and from that time on was an advocate of the use of brass shells on line shafts, etc. We had cast iron trucks, having the bearing caps held down with stud bolts, the original design calling for bolts about $\frac{5}{8}$ " in diameter and after these were pulled out, we kept on reaming out the holes and increasing the size of bolts up to about $1\frac{1}{4}$ " and then asked for a new truck. On some of the old style ladle cranes when it was necessary to change the shaft, we would send for the riggers to erect a scaffold and it would require anywhere from six to twenty-four hours to change a master shaft that would pass through a solid bearing in the side of the truck. This is one of the reasons we asked for bearings with split linings and the ability to lift out any shaft without disturbing any other shaft on the crane. We have been operating our ladle cranes about $3\frac{1}{2}$ years and we have never had occasion to feel that our safety ropes were called into action, yet I cannot feel that the installing of the safety ropes was a poor investment.

The question of wear on ropes was brought up. Might say that we designed our hoist with a safety factor of 8

and we tried to avoid reverse bends in the ropes wherever possible. We have ladle cranes on which we have ropes operating 2-½ years. The proper comparison cannot be made between the life of the ropes in two different plants as one may handle a greater tonnage than the other. It would be better to compare life of ropes on the basis of tonnage rather than time. On the new ladle crane that we installed about eight months ago, we have cut down the diameter of the ropes and have increased the number and I believe that we will benefit in the life of the ropes due to this change. In reference to the hooks for handling ladles, would say that we originally used forged steel hooks but are now using laminated hooks designed from plates.

By taking up the following questions when the buildings are being designed, a great deal of time and labor can be saved by submitting to the bridge company details for the erection of posts for lights, drilling of the girders for collector bar supports, bumpers, safety platforms and walks, etc. Steel buildings are generally quoted on a pound price basis and the punching of these holes would cost nothing if arranged for when the buildings are purchased but if not cared for at that time, it will be rather costly to do this work in the field.

In all buildings we provide a foot-walk the full length of the runway on both sides. We find it very convenient if a crane breaks down at some point in the middle of the building. We also have journal box platforms which are attached to the building girders at two or three points in the building. These platforms are 3-½ feet below the center line of the bridge truck wheel shafts.

Another question that should be considered in the design of the building is proper size of girders and runway rails. I know a number of cases where the cranes have had to take over the troubles of improper design in the buildings, that is the rails and girders are too light allowing runways to get out of line. In our soaking pit building we are using rails 175 lbs. to the yard, and in 3-½ years of service, we have not changed a track wheel or a brass and are still operating with the original wheels as furnished by the crane builder on our pit cranes. This is not due to

the design of the crane but rather to the design of the building and the runway.

In answer to Mr. Duncan's question, why a-c. cranes were not discussed? According to our specifications, all controllers, motors and brake solenoids will be supplied by the purchaser. We might buy a-c. or d-c. but this does not concern the crane manufacturer in any respect other than the number of conductor bars.

Mr. Cooper's question of why we mounted the brake on the armature shaft and not on the line shaft of bridge drive? The motor reduction on a bridge drive is about 4-1/2 to 1 and as the pounds pull on the brake band is proportionate to the decrease in speed, you have to have large brake band or excessive pressure applied to stop your crane, and for this reason, we have found it better to have the brake wheel on the armature shaft.

On this type of crane, we have specified dynamic braking with two band brakes, one on each of the armature and jack shafts, for the following reasons: If one brake goes out of commission, a crane can be operated until it is repaired, but we operate our cranes with brake band on the jack shaft materially looser than the armature brake band, as we have found that when an armature brake went out of commission and the jack shaft brake set tight there was a possibility of twisting the jack shaft.

In four years with dynamic braking cranes, we have not had a single case of trouble where we let the load run away, due to failure of dynamic brake.

On some cranes we are working on, we do not intend to put two brakes on, but will use a shoe brake on the armature shaft.

On all ladle cranes, I would positively use two brakes on each hoist drive. Four brake bands; one on each armature shaft, and one on each intermediate shaft, and these of band type.

MEMBERSHIP LIST

HONORARY MEMBERS

- DINKEY, A. C., Pres., Midvale Steel Co., Philadelphia, Pa. Sept. 25, 1911.
- DUNN, GANO, Pres., J. G. White Eng. Cor., 43 Exchange Place, New York City, N. Y. Sept. 30, 1912.
- GRACE, E. G., Pres., Bethlehem Steel Co., South Bethlehem, Pa. Res., 12th and Prospect Ave. Sept. 22, 1913.
- LAMME, B. G., Chief Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Sept. 14, 1914.
- STEINMETZ, CHARLES P., A. M., Ph.D., Chief Consulting Engineer, General Electric Co., Schenectady, N. Y. Res., Wendell Ave. Sept. 14, 1914.
- WHEELER, DR. SCHUYLER SKAATS, Pres., The Crocker-Wheeler Co., Ampere, N. J. Dec. 8, 1911.
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ACTIVE MEMBERS

- ABEL, CARTER N., Elect. Eng'r, Ebensburg Coal Co., Colver, Pa. Aug. 6, 1913.
- ALEXANDERS, A. W., Supt. Elect. Dept., Standard Steel Works, Burnham, Pa. Nov. 18, 1916.
- BECK, B. G., Elect. Eng'r., American Sheet & Tin Plate Co., Gary, Ind., Res., 720 Harrison Street. Oct. 1, 1910.
- BECK, WESLEY J., Director of Research, American Rolling Mills Co., Middletown, O. Res., 615 Alameda Ave. Sept. 18, 1916.
- BEDELL, C. E., Elect. Supt., Wheeling Steel & Iron Co., Wheeling, W. Va. Res., 104 20th Street, Warwood, W. Va. Oct. 1, 1910.
- BLACK, R. A., Chief Elec't., Forged Steel Wheel Co., Butler, Pa. Res., 441 Broad St. Oct. 1, 1910.
- BLAKE, S. J. Elect. Supt., Pittsburgh & Conneaut Dock Co., Conneaut, O. Res., 582 Main St. Oct. 1, 1908.
- BLAKE, W. H., Electrical Foreman, Pittsburgh Crucible Steel Co., Midland, Pa. Mar. 18, 1916.

- BOAK, R. C., Supt. Elec. Dept., Edgewater Steel Co., Oakmont, Pa.
Res. 316 7th Ave., Oakmont, Pa. Oct. 21, 1916.
- BOOHER, J. C., Chf. Elec., American Steel & Wire Co., Donora Steel
Works, Donora, Pa. Res., Box 204. March 17, 1917.
- BOOTH, JESSE J., Elect. Engr., Edgar Thomson Wks., Carnegie Steel
Co., Braddock, Pa. Res., 1228 Franklin Ave., Wilkinsburg,
Pa. Jan. 20, 1917.
- BREDE, EDWIN L., Asst. Chf. Elec., Mark Mfg. Co., Indiana Harbor,
Ind. Res. 9224 Commercial Ave., Chicago, Ill. Dec. 12, 1911.
- BRINKER, V. I., Supt. Elec. Dept., American Sheet & Tin Plate Co.,
Vandergrift, Pa. Res., 110 Farragut Ave. Oct. 1, 1909.
- BROWN, PETER D., Elect. Eng'r., Diamond O. Apr. 26, 1907.
- BUHL, WM., E. E., Union Electric Steel Co., Carnegie Pa. Res., Mans-
field Ave. March 17, 1917.
- BUTLER, WM. H., Jr., Asst. E. E., Midvale Steel Co., Philadelphia,
Pa. Res., 111 W. Sharpnack St., Germantown, Pa. Feb. 17, 1917.
- CANNEY, P. R., Elect. Eng'r., Minnesota Steel Co., 805 Wolvin
Bldg., Duluth, Minn. Aug. 21, 1913.
- CAPUTO, JAMES, Chf. Elec., Girard Rolling Mills, Girard Iron Co.,
Girard, O. Res., 24 Hancock St. Feb. 6, 1915.
- CEDERLUND, K. H., Supt. Elect. Dept., Duquesne Steel Works,
Carnegie Steel Co., Duquesne, Pa. Res., 724 S. Duquesne Ave.
July 1, 1912.
- CHAPMAN, JAS. F., Chief Elect'n., Colorado Fuel & Iron Co., Minne-
qua Works, Pueblo, Colo. Res., 521 Van Buren St. April 26,
1907.
- CHURCHILL, ARTHUR B., Elec. Supt., American Bridge Co., Am-
bridge, Pa. Res., 126 Park Road. Oct. 13, 1913.
- COBBLEDICK, MELVILLE W., Elect. Eng'r., Republican Iron & Steel
Co., Youngstown, O. Res., 148 East Marion Ave. Mar. 23, 1914.
- COEY, S. C., Ass't. Supt. Mech'l & Elect'l Dept., Youngstown Sheet
& Tube Co., Youngstown, O. Res., 258 Norwood Ave., Youngs-
town, O. May 2, 1914.
- COLLINS, PALMER, Asst. Supt., American Steel & Wire Co., South
Works, Worcester, Mass. Res., 78 Richmond Ave. Dec. 8, 1911.
- CONOVER, HUGH B., Supt. Elect. Dept., Carnegie Steel Co., Mingo
Junction, O. Res., 1446 W. Market St., Steubenville, O. July
1, 1913.
- CONRAD, CHAS. W., E. E., Remington Arms Co., Eddystone, Pa.
Box 197, Ridley Park, Penna. Nov. 18, 1916.
- COOMBE, BENJAMIN G., Chf. Elect'n., United Steel Co., Canton, O.
April 25, 1909.
- COOMBS, B. F., Supt. Elect. Dept., Aliquippa Works, Jones & Laugh-
lin Steel Co., Woodlawn, Pa. Res., 431 Highland Ave. May
2, 1914.
- COOPER, JOHN E., Chf. Elec'n., Carnegie Steel Co., Bellaire Steel
Works & Furnaces, Bellaire, O. Res., 4326 Harrison Street.
Oct. 1, 1910.

- CORBETT, CHARLES L., Chf. Elec'n, Carnegie Steel Co., Upper Union Mills, 33rd St., Pittsburgh, Pa. Res., 7909 Maderia St. Feb. 3, 1912.
- CORNWELL, B. A., Engr. Elec. Dept., Carnegie Steel Co., Ohio Works, Youngstown, O. Res., 18 W. Evergreen Ave. April 10, 1915.
- COX, HARRY A., M. M., Carnegie Steel Co., Donora Zinc Works, Donora, Pa. Res., 1328 Meldon Ave. P. O. Box 603. Apr. 26, 1907.
- CRAIGLOW, HARRY H., Plant Engr., The Buckeye Steel Castings Co., Columbus, O. Res., 716 Wilson Ave. May 20, 1916.
- CRONK, H. C., Chf. Elec'n., care River Fce. Co., Steel Dept., 4002 Dille Ave., Cleveland, O. Res., 2276 Grandview Ave., Shaker Heights. Dec. 8, 1912.
- DAVENPORT, EDWARD L., Asst. Chf. Elec., Carnegie Steel Co., New Castle, Pa. March 17, 1917.
- DAVENPORT, R. B., Supt. Elect. Dept., Carnegie Steel Co., New Castle, Pa. Res., 412 Garfield Ave. Apr. 26, 1907.
- DAVIS, H. E., Chf. Elec., Interstate Iron & Steel Co., East Chicago, Ind. Res., 707 144th St., East Chicago, Ind. March 17, 1917.
- DAVIS, JOHN B., M. M., American Steel Foundries Co., 36th St. & A. V. R. R., Pittsburgh, Pa. Res., 318 Lincoln Ave. May 20, 1916.
- DELANEY, JOHN S., Chf. Elect'n, Steel Mill Dept., Nat'l Enamelling & Stamping Co., Granite City, Ill. Res., 2128 State St., Granite City, Ill. June 13, 1914.
- DEWILER, W. FRANK, Asst. to Gen'l. Supt., Allegheny Steel Co., Tarentum, Pa. Res., 1121 Park St. Oct. 1, 1910.
- DONOVAN, JAS. D., Supt. Elec. Dept., Central Steel Co., Massillon, O. Res., 1214 State St. March 17, 1917.
- DUNCAN, ALLEN W., Elect. Sup't, Phillips Sheet & Tin Plate Co., Wierton, W. Va. Res., Box 33, March 18, 1916.
- EGAN, F. D., Steam & Elect. Eng'r., Pittsburgh Crucible Steel Co., Midland, Pa. Res., Beaver Ave. March 2, 1912.
- EGAN, LEONARD W., Asst. Steam & Elect. Engr., Pittsburgh Crucible Steel Co., Midland, Pa. May 20, 1916.
- EICHELBERGER, J. C., Engr., Pittsburgh Crucible Steel Co., Midland, Pa. March 17, 1917.
- FAIRGRIEVE, A. C., Chief Elect'n., Carnegie Steel Co., Upper & Lower Union Mills, West Federal St., Youngstown, O. Res., 67 Elmwood Avenue, Youngstown, O. Oct. 24, 1911.
- FARNSWORTH, W. H., Asst. Chf. Elec., The Youngstown Sheet & Tube Co., Youngstown, O. March 17, 1917.
- FARRINGTON, JAMES, Supt., Elect. Dept., La Belle Iron Works, Steubenville, O. Res., 322 Clinton St. Apr. 26, 1907.
- FIXTER, WALTER, Elec. Foreman, Baldwin Locomotive Works, 1518 Mt. Vernon St., Philadelphia, Pa. March 17, 1917.

- FOX, GORDON, E. E., Mark Mfg. Co., 2103 Conway Bldg., Chicago, Ill. Sept. 18, 1916.
- FRIEDLAENDER, E., Supt. Elect. Dept., Carnegie Steel Co., Edgar Thomson Works, Braddock, Pa. Res., 6544 Darlington Road, Pittsburgh, Pa. June 1, 1909.
- FRIES, J. E., Chf. Elect. Engr., Tennessee Coal, Iron & R. R. Co., Ensley, Ala. Res. 1484 Milner Crescent, Birmingham, Ala. Oct. 21, 1916.
- GALBREATH, L. F., Elect. Eng'r., West Penn Steel Co., Brackenridge, Pa. Res., 50 Vine Street, Natrona, Pa. Oct. 1, 1910.
- GALE, R. F., E. E., Midvale Steel Co., Philadelphia, Pa. Res., 5031 Knox St., Germantown, Pa. Feb. 17, 1917.
- GERHARDT, R. B., Supt. Elec. Dept., Bethlehem Steel Co., Maryland Plant, Sparrows Point, Md. Res., 619 C St. Sept. 9, 1916.
- GHOSH, S., Chf. Elect'n., Tata Iron & Steel Co., Ltd., Sakchi, India. Aug. 14, 1915.
- GILLIS, J. P., Chief Engr., McKeesport Sheet & Tin Plate Co., McKeesport, Pa. Res., Box 236, E. McKeesport. Jan. 15, 1916.
- GILSON, BARNEY W., Elect. Supt., Carnegie Steel Co., Ohio Works, Youngstown, O. Res., Cor. Lora & Ford Aves. Oct. 1, 1910.
- GLEDHILL, JOHN H., E. E., Baldwin Locomotive Wks., Philadelphia, Pa. Res., 1164 Wagner Ave. Nov. 18, 1916.
- GRAY, CHAS. H., M. M. & Chf. Elec., Ft. Pitt Steel Casting Co., McKeesport, Pa. Res., 3320 Versailles Ave. Sept. 18, 1916.
- HALL, W. S., E. E., South Wks., Illinois Steel Co., So. Chicago, Ill. Feb. 17, 1917.
- HANEY, G. W., Chief Elect., Brier Hill Steel Co., Youngstown, O. March 18, 1916.
- HARPER, CHAS. W., Chf. Elec., Keystone Steel & Wire Co., Peoria, Ill. Res., 515 Glen Oak Ave. Sept. 7, 1916.
- HATTON, MERLE W., M. M., Mesta Machine Co., Homestead, Pa. Res., 404 10th St., Munhall, Pa. March 18, 1916.
- HAZEN, COMER D., Chief Elect'n., Coke Plant, Illinois Steel Co., Gary, Ind. Res., University Club. Dec. 16, 1911.
- HEALEY, G. T., Chf. Elect'n., Steel Works, American Steel & Wire Co., Cleveland, O. Feb. 26, 1912.
- HELANDER, LINN, Foreman, Engineering Test Dept., Pittsburgh Crucible Steel Co., Midland, Pa. Res., Box 574. March 17, 1917.
- HENDERSON, SAMUEL L., Elec. Supt., American Steel & Wire Co., Central Furnaces, Cleveland, O. Res., 1307 Rowley Ave. Oct. 1, 1910.
- HOLCOMB, A. B., Elect. Supt., Standard Tin Plate Co., Canonsburg, Penna. Res., 511 McNair Ave., Wilkinsburg, Pa. Sept. 18, 1916.
- HUEY, RAY S., Supt. Duluth Plant, Universal Portland Cement Co., New Duluth, Minn. Res., 1428 Jefferson St., Duluth, Minn. June 13, 1914.
- HUMPTON, L. R., Chf. Elec., Parkesburg Iron Co., Parkesburg, Pa. Dec. 16, 1916.

- HUSSEY, ROWLAND M., Asst. Supt. Elec. Dept., Aliquippa Works, Jones & Laughlin Steel Co., Woodlawn, Pa. Box 1213. March 17, 1917.
- JACKSON, WM., Chf. Elect'n., Carnegie Steel Co., Rankin, Pa. Res., 1210 Margaret St., Munhall, Pa. Aug. 2, 1912.
- JEFFERIES, ERNEST S., Elect. Engr., Steel Co. of Canada, Hamilton, Ont. Res., 96 Herkimer St. July 17, 1914.
- JONES, NOBLE, Master Mech., Sharon Steel Hoop Co., Sharon, Pa. Res., 17 Baldwin Ave. Oct. 1, 1908.
- JONES, O. R., Chf. Electrician, Youngstown Iron & Steel Co., Youngstown, O. Res., 914 Belmont Ave. April 26, 1907.
- KAFFER, CHAS A., Elect. Supt., Bethlehem Steel Co., Saucon Plant, South Bethlehem, Pa. Res., 310 7th Ave., Bethlehem, Pa. June 1, 1908.
- KELLY, JOHN F., Genl. Foreman, Electrical Dept. National Tube Co., McKeesport, Pa. Res., 715 Fawcett St. May 1, 1915.
- KENNEDY, P. C., Asst. Elect. Supt., Edgewater Steel Co., Oakmont, Pa. Res., 409 Woodlawn Road. March 17, 1917.
- KENNEDY, WALTER C., Chf. Engr., Standard Seamless Tube Co., Ambridge, Pa. Res., 1325 3rd Ave., New Brighton, Pa. June 14, 1912.
- KENNEY, JOHN S., Chf. Elec., Wheeling Steel & Iron Co., Yorkville, O. Res., Tiltonville, O. March 17, 1917.
- KING, WM. J., Chf. Elec., Coatesville Boiler Works, Coatesville, Pa. Res., 243 Harmony St., Coatesville, Pa. March 17, 1917.
- KITTREDGE, FRANK H., Chf. Elect'n., Illinois Steel Co., Collins and Francis Sts., Joliet, Ill. Res., 307 Richards St. Apr. 26, 1907.
- KNAPP, DAVID R., Elec. Engr., Eastern Steel Co., Pottsville, Pa. Res., 724 Center St. Oct. 1, 1910.
- LANCKTON, CLARK S., Asst. Supt., Elect. Dept., Midvale Steel & Ordnance Co., Worth Bros. Plant, Coatesville, Pa. Res., 1236 E. Main St., Coatesville, Pa. June 1, 1909.
- LAUGHLIN, H. HUGHART, Elect. Eng'r., Jones & Laughlin Steel Co., 2709 Carson St., Pittsburgh, Pa. Res., Woodland Road. Oct. 1, 1908.
- LEWIS, H. A., Elect. Supt., Alan Wood Iron & Steel Co., Norristown, Pa. Res., 212 Stanbridge St. Apr. 26, 1907.
- LINDSTROM, J. D., Supt. Power Equipment, Shelby Steel Tube Co., Ellwood City, Pa. Feb. 2, 1912.
- LITTLEBOY, T. G., Electrical Eng'r., Brymbo Steel Co., North Wales, England. June 1, 1909.
- LOCKIE, JOHN W., Chf. Elect., Wickwire Steel Co., Buffalo, N. Y. Res., 216 Dearborn St. May 20, 1916.
- MAHER, J. P., Asst. Elec. Supt., Mark Mfg. Co., 9224 Commercial Ave., Chicago, Ill. March 17, 1917.
- MALONEY, JAS., Chf. Elec., Superior Steel Co., Carnegie, Pa. Res., 4604 Carrol St., Wilkinsburg, Pa. Sept. 18, 1916.

- MANDEVILLE, LEE H., Chf. Elec., Natl. Pressed Steel Co., Massillon.
O. Res., 1223 Lawrence Rd., Canton, O. Jan. 20, 1917.
- MAURER, WM. F., Elec. Cons. Foreman, American Rolling Mills Co.,
Middletown, O. July 11, 1916.
- MAY, WALTER H., Chf. Elect'n, Cleveland & Pgh. Ore Docks, 1449
Olivewood Ave., Lakewood, O. Oct. 3, 1914.
- MENK, C. A., Supt. Elect. Dept., Carnegie Steel Co., Homestead
Works, Munhall, Pa. Res., 502 Eleventh Ave. Apr. 26, 1907.
- MILLER, A. E., Chf. Elect. Allegheny Steel Co., Brackenridge, Pa.
Res., Box 385. May 20, 1916.
- MILLER, CHARLES E., Supt. Elect. Dept., Carnegie Steel Co., Clair-
ton, Pa. Res., 251 Halcomb Ave. Sept 25, 1911.
- MILLS, JAMES L., Elect. and Mech. Eng'r., North Works, Illinois
Steel Co., 1319 Wabansia Ave., Chicago, Ill. Res., 1326 Green-
wood Ave., Wilmette, Ill. Feb. 4, 1913.
- MOORE, HOWARD J., Chf. Elect'n, Newburg Steel Works, American
Steel & Wire Co., Cleveland, O. Res., 8815 Walker Ave., Cleve-
land, O. June 13, 1914.
- MORGAN, J. A., Asst. Supt. Elec. Dept., Edgar Thomson Works,,
Carnegie Steel Co., Braddock, Pa. Res., 432 Frazier Street,
Braddock, Pa. Feb. 7, 1914.
- MOSLEY, H. C., Chf. Elec'n, Whitaker-Glessner Co., Portsmouth, O.
Res., 633 6th st., Portsmouth, O. May 2, 1914.
- MULLALLY, R. J., Res., 38 Thornton Ave., Youngstown, O. July 1,
1912.
- MCCAIN, HARRY B., Chf. Elec., Steel Hoop Mills, Carnegie Steel Co.,
McCutcheon Mills, N. S., Pittsburgh, Pa. Res., 151 Teece Ave.,
Bellevue, Pa. March 17, 1917.
- McFADYEN, D. W., Chf. Elec'n., Universal Portland Cement Co.,
Universal, Pa. Res., 216 Bessemer Ave., East Pittsburgh, Pa.
Sept. 5, 1911.
- McFEATERS, GEORGE H., Chf. Elec'n., Lorain Steel Co., Johnstown,
Pa. P. O. Box, 522. April 26, 1907.
- McILYAR, C. C., Chf. Elec'n., Otis Steel Co., Riverside Plant, West
14th St., Cleveland, O. Feb. 7, 1914.
- McINTOSH, R. L., Chf. Elec'n., Inland Steel Co. Res., 3509 Fir St.,
Indiana Harbor, Ind. July 11, 1912.
- NIMZ, WILLIAM, Chf. Elect., National Malleable Casting Co., Cleve-
land, O. June 17, 1916.
- NYE, RALPH D., Elect. Engr., United Steel Co., Canton, O. Feb.
7, 1914.
- O'DONOVAN, J. S., Chf. Elec'n., Spang, Chalfant & Co., Etna, Pa.
Res., 237 Clifton Ave., Sharpsburg, Pa. June 1, 1909.
- OLDHAM, W. H., Asst. Supt. Elect. Dept., Cambria Steel Co., Johns-
town, Pa. Res., 508 Cypress St. May 1, 1915.
- OSCHMANN, W. O., Elect. Eng'r., Oliver Iron & Steel Co., Pittsburgh,
Pa. Res., 2417 Osgood St. March 2, 1912.

- PARKHURST, C. W., Supt., Elect. Dept., Cambria Steel Co., Johnstown, Pa. Res., 342 Luzerne St. Oct. 1, 1908.
- PATTERSON, ROBT. F., Elec. Eng'r, Pressed Steel Car Co., Pittsburgh, Pa., & Western Steel Car & Foundry Co., Chicago, Ill., care Pressed Steel Car Co., Pittsburgh, Pa. Res., 1226 Sixth Ave., Beaver Falls, Pa. Feb. 12, 1915.
- PENDLEBERRY, HENRY L., Chf. Elect., Pittsburgh Steel Products Co., Monessen, Pa. Res., Lock No. 4, Washington County, Pa. Sept. 5, 1914.
- PENMAN, J. R., Chf. Elec., Reading Iron Co., Reading, Pa. Res., 408 Windsor St., Reading, Pa. Feb. 17, 1917.
- PETTY, D. M., Supt. Elect. Dept., Bethlehem Steel Co., South Bethlehem, Pa. Res. 53 Market St. July 1, 1911.
- PLACE, A. G., Chf. Elec., Youngstown Sheet & Tube Co., Youngstown, O. Res., 522 Bryson St. Jan. 9, 1915.
- POWERS, JOHN E., Chf. Elect., American Steel & Wire Co., Farrell Works, Farrell, Pa. May 20, 1916.
- PROUDFOOT, C. S., Asst. Elect. Supt., Carnegie Steel Co., Homestead Works, Munhall, Pa. Res., 624 13th Ave. Oct. 1, 1908.
- RANKIN, LEWIS R., Chief Elec'n., Carnegie Steel Co., Farrell, Pa. Res., 59 Prindle Ave., Sharon, Pa. June 1, 1909.
- REARDON, W. E., Chf. Elec., Sharon Steel Hoop Co., Sharon, Pa. Res., 4 Erie St. May 1, 1915.
- REED, JOHN C., Elect. Eng'r., Pennsylvania Steel Co., Steelton, Pa. Res., 2635 S. Second St. April 26, 1907.
- REEVE, GEO., Chf. Elec., Fort Pitt Malleable Iron Co., McKees Rocks, Pa. Res., 1412 Orator St., Pittsburgh, Pa. Feb. 17, 1917.
- REICHERT, A. L., Chf. Elect'n., Upson Nut & Bolt Co., Bolt & Nut Dept., Cleveland, O. Res., 1912 View Road. Sept. 8, 1915.
- RENIERS, JAMES H., Elect. Eng'r., Pittsburgh Screw & Bolt Co., Preble Ave., N. S., Pittsburgh, Pa. Res., 6477 Aurelia St. Aug. 12, 1913.
- RESE, WM. F., E. E., Trumbull Steel Co., Warren, O. Res., 304 N. Park Ave., Warren, O. Jan. 20, 1917.
- RICHARDSON, G. W., Elect. Supt., American Bridge Co., Pencoyd Iron Works, Pencoyd, Pa. Res., 2559 N. 33rd St., Philadelphia, Pa. April 26, 1907.
- RIGGS, JAS. S., Elect. Supt., Jones & Laughlin Steel Co., Pittsburgh, Pa. Res., 203 East End Ave. Oct. 1, 1910.
- RILES, JAMES, Elect. Eng'r., A. M. Byers Co., 6th & Bingham Sts., South Side, Pittsburgh, Pa. Res., 111 Rustic Ave., Mt. Oliver Station, Pittsburgh, Pa. Dec. 26, 1912.
- ROBINSON, MILLARD S., Chf. Elec., American Steel & Wire Co., Wire Works, Donora, Pa. Res., 114 11th St. Oct. 3, 1914.
- ROEMER, GEO. R., Chf. Elec., Trumbull Steel Co., Warren, O. Nov. 18, 1916.

- ROSS, EMMETT W., Night Foreman, Elect. Dept., Remington Arms Co., Eddystone, Pa. Res., 620 West St., Camden, N. J. Nov. 18, 1916.
- ROTT, W. C., Engr., Julian Kennedy, 1217 Bessemer Bldg., Pittsburgh, Pa. March 17, 1917.
- ROWELL, C. D., Chf. Elec'n., Pittsburgh Steel Co., Monessen, Pa. Res., 476 Reed Ave., Monessen, Pa. Feb. 7, 1914.
- RUGGLES, MORRIS L., Chf. Elect., American Steel & Wire Co., Cuyahoga Works, Cleveland, O. Res., 4159 E. 95th. St., S. E. May 20, 1916.
- SCHAEFFER, GEO. H., Elec'n., Carpenter Steel Co., Reading, Pa. Res., 1354 Mineral Springs Road. Sept. 12, 1913.
- SCULLY, J. D., Gen'l. Foreman, Electrical Dept., National Works, National Tube Co., McKeesport, Pa. Res., 810 West Park Way. Sept. 8, 1915.
- SHEPERD, RUSSELL R., Elect Supt., Mark Mfg. Co., Indiana Harbor, Ind. Res., 1122 E. 55th St. Dec. 8, 1911.
- SCHWARZNAU, EDGAR J., Chf. Estimator, American Sheet & Tin Plate Co., Pittsburgh, Pa. Res., Mt. Lebanon, Pa. Dec. 16, 1916.
- SEAGLE, C. B., Elect. Engr., Mech. Eng., American Bridge Co., Ambridge, Pa. Sept. 8, 1915.
- SHOEMAKER, R. S., Supt. Maintenance Dept., American Rolling Mill Co., Middletown, O. June 1, 1909.
- SHOVER, B. R., E. E., 704 Diamond Bank Bldg., Pittsburgh, Pa. May, 24, 1907.
- SIMONICH, J. L., Engr., Test Dept., Pittsburgh Crucible Steel Co., Midland, Pa. March 17, 1917.
- SKELLY, C. B., Chf. Elec., Newburg Steel Wks., American Steel & Wire Co., Cleveland, O. Res., 3517 E. 103rd St. Sept. 7, 1916.
- SMITH, EDWARD C., Electrical Eng'r., Harrisburg Pipe & Pipe Bending Co., Harrisburg, Pa. Res., 2043 Green St. Oct. 1, 1909.
- SMITH, GEO. H., Chf. Elec., Donner Steel Co., Buffalo, N. Y. Res., 156 Folger St. July 25th, 1916.
- SNYDER, W. T., Supt. Elect. Dept., National Tube Co., McKeesport, Pa. Res., 1511 Centennial St. Oct. 1, 1909.
- SPONSEL, J. G., Acting M. M. and M. E., American Bridge Co., Gary Plant, Gary, Ind. Res., 286 Chase St. Apr. 15, 1916.
- STANSFIELD, HENRY, Chief Elec'n., National Malleable Castings Co., Sharon, Pa. Res., 35 South Oakland Ave. Mar. 16, 1913.
- STEPHENS, ROY E., Asst. M. M., Follansbee Bros. Co., Follansbee, W. Va. Res., Virginia Ave. July 10, 1915.
- STEVENS, F. W., Elect. Engr., Brill Car Works, Philadelphia, Pa. Res., 2009 60th St., W. April 26, 1907.
- STURGESS, G. M., Night Supt., Elect. Dept., Indiana Steel Co., Gary, Ind. Apr. 26, 1907.
- THOMAS, J. W., 918 Commerce Bldg., Erie, Pa. Mar. 7, 1913.

- THOMPSON, WM. H., Elect. Eng'r., 132 Weldon Ave., Mansfield, O. May 20, 1916.
- TOWNSEND, A. J., V. P., Natl. Pressed Steel Co., Massillon, O. Res., 1415 Yale Ave., Canton, O. Jan. 20, 1917.
- TSCHENTSCHER, R., Genl. Supt., Steel Plant, Keystone Steel & Wire Co., Peoria, Ill. Oct. 1, 1908.
- TUCKER, ALLEN M., Chf. Elec., American Bridge Co., Gary, Ind. Res., 221 Ellsworth Ave. Sept. 7, 1916.
- TYNES, T. E., Elect., Eng'r., Lackawanna Steel Co., Lackawanna, N. Y. Res., 226 Woodward Ave., Buffalo, N. Y. June 1, 1909.
- WALDNER, ADAM J., Chf. Elect., American Steel Foundry Co., Indiana Harbor, Ind. Res., 4131 Houston Ave., Chicago, Ill. Oct. 21, 1916.
- WALES, S. S., E. E., Carnegie Steel Co., 1073 Frick Bldg., Pittsburgh, Pa. Dec. 16, 1916.
- WALTON, A. B., Elect. Supt., American Ship Building Co., Lorain, O. May 20, 1916.
- WATTERS, W. E., Mas. Mech., National Malleable Casting Co., Melrose Park, Ill. Res., 410 17th Ave., Maywood, Ill. Oct. 1, 1910.
- WELSH, ROBERT B., Chief Elec'n., American Sheet & Tin Plate Co., Canal Dover, O. April 1, 1912.
- WENTZ, E. H., Supt. Elect. Dept., The National Tube Co., Lorain, O. Res., 109 Columbus St., Elyria, O. Sept. 28, 1911.
- WILEY, FRANK A., Electrical Supt., Wisconsin Steel Co., South Chicago, Ill. Res., 2611 E. 74th Place, Chicago, Ill. June 1, 1909.
- WILSON, A. S., Elec. Supt., Apollo Steel Co., Warren Ave., Apollo, Pa. Res., North 5th St. Aug. 8, 1913.
- WILSON, J. H., Asst. Genl. Supt., The American Rolling Mill Co., Middletown, O. Res., 824 Stanley Ave. Oct. 1, 1910.
- WINSLOW, G. H., Consulting Eng'r., Route 4, R. F. D. 97 A., Chagrin Falls, O. April 26, 1915.
- WOODHULL, FRED H., Supt. Elect. Dept., Lukens Iron & Steel Co., Coatesville, Pa. Res., 104 S. Sixth St. April 26, 1907.

ASSOCIATE MEMBERS

- ACKARD, CHAS. B., Elect'n., Carnegie Steel Co., Schoen Steel Wheel Works, McKees Rocks, Pa. Res., 726 Woodward Ave. April 10, 1915.
- AHRENS, A. G., Sales Eng'r., Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa. Res., Amber Club, 123 N. Negley Ave., Pittsburgh, Pa. Sept. 12, 1913.
- ALBRECHT, J. H., Controller Engr., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Res., 3202 Perrysville Ave., Pittsburgh, Pa. Nov. 13, 1915.

- ALEXANDER, J. W., Mgr., Repair Dept., Crescent Electric Co., Pittsburgh, Pa. Res., 2525 Penn Ave. Oct. 9, 1915.
- ALLEN, A. H., Phila. Mgr., Allen Bradley Co., & Triumph Electric Co., 1121 Liberty Bldg., Philadelphia, Pa. Feb. 17, 1917.
- ANDERSON, A. A., Mgr. Central Sales Dept., Standard Underground Cable Co., 700 Westinghouse Bldg., Pittsburgh, Pa. Res., R. F. D. No. 2, Glenshaw, Pa. April 10, 1912.
- ANDRESEN, A. M., Dist. Sales Mgr., Van Dorn Electric Tool Co., 701 Empire Bldg., Pittsburgh, Pa. Res., 1010 Jancey St., E. E. Sept. 8, 1915.
- ANDREWS, JAS. M., Commercial Eng'r., General Electric Co., Schenectady, N. Y. Res., 13 Stratford Road. Dec. 16, 1911.
- ANDREWS, ROBERT M., P. O. Box 353, Parkersburg, W. Va. June 17, 1916.
- ANTHONY, R. B., Genl. Mgr., The E. A. Wilcox Co., 6330 Stony Island Ave., Chicago, Ill. July 10, 1915.
- ARENBERG, A. L., Illuminating Engr., Central Electric Co., 320 S. 5th Ave., Chicago, Ill. Sept. 18, 1916.
- ATKINSON, C. N., Open Hearth Dept., Pittsburgh Crucible Steel Co., Midland, Pa. March 17, 1917.
- BAKER, G. M., Sales Eng'r., General Electric Co., 1314 Oliver Bldg., Pittsburgh, Pa. Res., 416 Hutchinson Ave., Edgewood Park, Pittsburgh, Pa. Feb. 6, 1915.
- BAKER, R. L., Power Sales Eng'r., Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill. April 10, 1915.
- BARNHOLDT, H. L., Designing Eng., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Res., 1229 Biltmore Ave., Dormont, Pittsburgh, Pa. Oct. 3, 1912.
- BARNUM, T. E., Chf. Engr., Cutler Hammer Mfg. Co., Milwaukee, Wis. Jan. 20, 1917.
- BATTEY, WM. A., Eastern Sales Mgr., Shepard Electric Crane & Hoist Co., Room 1269, 50 Church St., New York, N. Y. Feb. 17, 1917.
- BECK, C. A., Dist. Mgr., Reliance Electric & Engineering Co., 1113 Harrison Bldg., Philadelphia, Pa. Res., 52nd & Sampson St. March 18, 1916.
- BEDDOE, THOS. E., Sales Engr., Cutler Hammer Mfg. Co., 1339 People's Gas Bldg., Chicago, Ill. Res., 851 Windsor Ave. Aug. 19, 1916.
- BELL, FRED G., Sales Engr., Electro Dynamic Co., Bayonne, N. J. March 17, 1917.
- BELL, S. S., Elec., A. Garrison Foundry Co., Pittsburgh, Pa. Res., Oak Station, Pa. Nov. 18, 1916.
- BENDER, CLAUDE W., Gen. Mgr., Specialty Division, National Lamp Works, Nela Park, Cleveland, O. Res., 1781 E. 68th St., Cleveland, O. Feb. 3, 1912.
- BENNETT, HERBERT G. R., Special Engr., Carnegie Steel Co., Union Mills, Youngstown, O. Res., 366 Lexington Ave. Aug. 5, 1914.

- BERCAW, O. M., Salesman, The Cutter Electric & Mfg. Co., 1007 Park Bldg., Pittsburgh, Pa. Res., 516 Holmes St., Wilksburg, Pa. Feb. 21, 1914.
- BERGMANN, C. N., Supt., The Pittsburgh Electrical & Machine Wks., Barker Place, Pittsburgh, Pa. Res., 3544 McClure Ave. Oct. 9, 1915.
- BERRSFORD, A. W., V. P. & Gen'l. Mgr., The Cutler-Hammer Mfg. Co., Milwaukee, Wis. Res., 201 Prospect Ave. Dec. 8, 1911.
- BIGGERT, J. P., Dist. Rep., The Tool Steel Gear & Pinion Co., 1537 H. W. Oliver Bldg., Pittsburgh, Pa. Res., 420 Denniston Ave. April 15, 1916.
- BILLINGTON, H. E., Pgh. Mgr., Automatic Elec. Co., 604 1st Natl. Bank Bldg., Pittsburgh, Pa. Res., 506 Maryland Ave. Jan. 20, 1917.
- BINGAY, R. V., Pres., Pittsburgh Transformer Co., Adams St. and Preble Ave., N. S., Pittsburgh, Pa. Dec. 8, 1911.
- BORLAND, D. S., Erecting Engr., Crocker Wheeler Co., Pittsburgh & Cleveland District, Pittsburgh, Pa. March 17, 1917.
- BRADLEY, H. L., Sec. & Genl Mgr., Allen-Bradley Co., 495 Clinton St., Milwaukee, Wis. Res., 764 Stowell Ave. Sept. 30, 1912.
- BRANDON, G. R., Vice Pres. & Gen'l. Mgr., Whiting Foundry Equipment Co., 1245 Marquette Bldg., Chicago, Ill. March 6, 1915.
- BRANDT, WM. VAN C., Mgr., Pgh. Office, The Electric Storage Battery Co., Keystone Bldg., Pittsburgh, Pa. Res., 447 Rosedale St., Wilksburg, Pa. Jan. 9, 1915.
- BRECK, GEO. D., Sales Mgr., Babcock-Wilcox Co., 1110 Farmer's Bank Bldg., Pittsburgh, Pa. June 5, 1915.
- BRESLOVE, JOS., Sales Eng'r., Allis-Chalmers Co., 1209 Park Bldg., Pittsburgh, Pa. Res., 5876 Darlington Road. Oct. 10, 1913.
- BRIGGS, W. C., Sales Eng'r., Shepard Electric Crane & Hoist Co., 50 Church St., New York, N. Y. Res., Erie Ave. & Springfield Road, Elizabeth, N. J. Dec. 8, 1911.
- BRITTINGHAM, FRANK J., Pgh. Mgr., Cleveland Crane & Engineering Co., First National Bank Bldg., Pittsburgh, Pa. Res., 1432 Barnsdale St. June 17, 1916.
- BROOKS, L. C., Elect. Eng'r., Industrial Control Dept., General Electric Co., Route 49, Schenectady, N. Y. Res., 95 Ralston Road. June 5, 1915.
- BROSIUS, EDGAR E., Contracting Eng'r., 1611 Benedum Trees Bldg., Pittsburgh, Pa. Res., 5720 Forbes St. Dec. 8, 1911.
- BUCHANAN, J. R., Local Engr., General Elec. Co., 1301 Oliver Bldg., Pittsburgh, Pa. Feb. 17, 1917.
- BUCKLEY, SYDNEY, Engr., Crane Dept., Niles-Bement-Pond Co., Mifflin & Meadow Sts., Philadelphia, Pa. March 17, 1917.
- BURD, FRANK J., Sales Eng'r., Cutler-Hammer Mfg. Co., Farmer's Bank Bldg., Pittsburgh, Pa. Res., 1224 Mill St., Wilksburg, Pa. March 6, 1915.

- BURLEIGH, ARTHUR C., Salesman, The Chicago Pneumatic Tool Co., 10-12 Wood St., Pittsburgh, Pa. April 15, 1916.
- BURNETT, L. H., Asst. to Pres., Carnegie Steel Co., 1127 Carnegie Bldg., Pittsburgh, Pa. Res., 5809 Marlborough Ave. Dec. 15, 1913.
- BURNS, WM. J., Mgr. & Treas., The Neff-Burns Electric Co., Wheeling, W. Va. Res., 1058 Market St. Feb. 6, 1915.
- CALDWELL, PAUL, Sales Eng'r., General Electric Co., 1315 Oliver Bldg., Pgh., Pa. Res., 7819 Maderia St., Pittsburgh, Pa. Sept. 29, 1912.
- CALIBAUGH, J. G., Gen. Mgr., Calibaugh Self Lub. Carbon Co., 1503 Columbia Ave., Philadelphia, Pa. Res., 1100 Columbia Ave. June 17, 1916.
- CAMERON, ARTHUR, Sales Engr., General Electric Company of Michigan, Detroit, Mich. August 10, 1915.
- CAMERON, W. D., Sales Agent, General Electric Co., Monadnock Bldg., Chicago, Ill. Res., 1644 Lunt Ave., Rogers Park. Jan. 15, 1916.
- CASTLE, S. N., Commercial Engr., General Elec. Co., 30 Church St., New York, N. Y. Res., Davenport Neck, New Rochelle, N. Y. Jan. 20, 1917.
- CHESROWN, E., District Eng'r., Westinghouse Elect & Manufacturing Co., 1804 Union Bank Bldg., Pittsburgh, Pa. Res., 1401 N. St. Clair St. Dec. 8, 1911.
- CLARK, WALTER R., Mecl. Engr., Bridgeport Brass Co., Bridgeport, Conn. Res., 1875 Park Ave. March 17, 1917.
- COATES, C. B., Mgr. Elect. Dept., Chicago Pneumatic Tool Co., 343 So. Dearborn St., Chicago, Ill. Res., 4822 Dorchester Ave. Sept. 7, 1916.
- COCHRAN, C. H., Salesman, Gen'l Electric Co., Witherspoon Bldg., Philadelphia, Pa. Res., 5328 Webster St., W., Philadelphia, Pa. Oct. 3, 1914.
- COGSWELL, WESLEY H., Sales Eng'r., John A. Crowley Co., 811 Park Bldg., Pittsburgh, Pa. Res., 560 East End Ave. December 18, 1915.
- CONE, C. F., Sales Agent, General Electric Co., Oliver Bldg., Pittsburgh, Pa. Res., 6463 Aurelia St. Feb. 24, 1914.
- CORBETT, J. O., Pres. & Treas., Corbett & DeCoursey Co., 705 Columbia Bank Bldg., Pittsburgh, Pa. Res., 2914 Espy St. Oct. 10, 1913.
- COSDON, HOUSTON, Foreman, Elec. Dept., Midvale Steel Co., Philadelphia, Pa. Res., 4444 Chadwick St. Feb. 17, 1917.
- COUCHEY, LESTER H., Illuminating Eng'r., National Carbon Co., Cleveland, O. Res., 1556 Cohasset Ave., Lakewood, O. June 5, 1915.
- CRISS, GEO. H., Salesman Westinghouse Electric & Mfg. Co., 1806 Union Bank Bldg., Pittsburgh, Pa. Res., 626 Warrington Ave. May 1, 1915.

- CROFOOT, C. M., So.-Western Sales Manager, Crouse-Hinds Co., 2302 Union Central Bldg., Cincinnati, O. Res., 2215 Slane Ave., Norwood, O. Dec. 15, 1913.
- CROSBY, FRED BICKFORD, Elect. Eng'r., General Electric Co., Schenectady, N. Y. Res., 650 Rugby Rd. Aug. 30, 1913.
- CURTIS, JOHN L., Local Engr., General Electric Co., 1001 Electric Bldg., Buffalo, N. Y. Res., 409 Elmwood Ave. Dec. 16, 1916.
- DARBY, H. F. JR., Chicago Dist. Mgr., Cutter Electric & Mfg. Co., Monadnock Bldg., Chicago, Ill. May 2, 1912.
- DARLING, DANIEL G., Sales Eng'r., Reliance Elect. & Eng. Co., Ivanhoe Road, Cleveland, O. Res., 15403 Park Grove Ave., Cleveland, O. March 28, 1914.
- DAULER, C. S., District Mgr., The Electric Controller & Mfg. Co., 2698 E. 79th St., Cleveland, O. Res., 1423 E. 109th St. Sept. 12, 1912.
- DEAN, WM. T., District Mgr., Power and Mining Dept., General Electric Co., 1025 Monadnock Bldg., Chicago, Ill. Res., 779 Greenwood Ave., Glencoe, Ill. Dec. 26, 1911.
- DeCOURSEY, W. L., Sales Mgr., Economy Fuse & Mfg. Co., 2223 Farmers Bank Bldg., Pittsburgh, Pa. Res., 216 Elm St., Edgewood Park, Pa. Sept. 8, 1915.
- DEXTER, JOHN M., Salesman Corliss Carbon Co. General Delivery, Pittsburgh, Pa. Nov. 7, 1914.
- DICKINSON, EDGAR D., Eng'r Steam Turbines, General Electric Co., Schenectady, N. Y. Res., 111 Brandywine Ave. Aug. 9, 1912.
- DIEHL, D. L., Pres., Simplex Construction Co., Union Trust Bldg., Harrisburg, Pa. Jan. 20, 1917.
- DOLE, ARTHUR L., Salesman, Electric Controller & Mfg. Co., 1539 Oliver Bldg., Pittsburgh, Pa. Res., 6625 Ridgeville St., Pittsburgh, Pa. Feb. 7, 1914.
- DONNAN, DAVID M., Mgr., The Electrical Engineering & Mfg. Co., First National Bank Bldg., Pittsburgh, Pa. Res., 210 Bellefield Ave. Feb. 6, 1915.
- DOWNS, JAS. R., Mgr. Pgh. Office, Burke Electric Co., 739 Oliver Bldg., Pittsburgh, Pa. Res., 318 First Ave., Aspinwall, Pa. June 5, 1915.
- DRATZ, PAUL A., Chicago Rep., Whiting Foundry Equipment Co., 1245 Marquette Bldg., Chicago, Ill. Res., Harvey, Ill. May 1, 1915.
- DUFFEY, A. J., Sales Agt., P. & M. Dept., General Electric Co., Monadnock Bldg., Chicago, Ill. March 17, 1917.
- DYER, A. C., Dist. Mgr., Electric Controller & Mfg. Co., 1539 Oliver Bldg., Pittsburgh, Pa. Res., 5704 Callowhill St. Nov. 21, 1916.
- EDGEComb, HENRY R., Chf. Engr., Speer Carbon Co., St. Marys, Pa. Res., 403 Walnut St. Nov. 18, 1916.
- ELLIOTT, J. N., Mgr., The Elliott-Thompson Elect. Co., 205 St. Clair Ave., N. E., Cleveland, O. Res., 1552 Wagar Ave. Sept. 8, 1915.

- EMMONS, G. C., Sales Engr., Chicago Pneumatic Tool Co., 10-12 Wood St., Pittsburgh, Pa. Nov. 18, 1916.
- ESTILL, D. C., Sales Engr., National Carbon Co., 511 Park Bldg., Pittsburgh, Pa. Res., 4607 Forbes St. Dec. 18, 1915.
- EUSTICE, A. L., Pres. Economy Fuse & Mfg. Co., Kinzie & Orleans Sts., Chicago, Ill. Res., 1152 Farwell Ave. Oct. 3, 1914.
- EVANS, G. G., Safety Director & Claim Agt., The Brier Hill Steel Co., Youngstown, O. Res., Girard, O. March 17, 1917.
- EVANS, WALTER H., Dept. Mgr., Western R. R., U. S. Metal & Mfg. Co., 1964 McCormick Bldg., Chicago, Ill. Sept. 18, 1916.
- FARRAR, NORMAN P., Dist. Mgr., Shepard Electric Crane & Hoist Co., 801 Bulletin Bldg., Philadelphia, Pa. Res., 2952 N. 12th St. April 2, 1912.
- FAWCUS, THOMAS, President Fawcus Machine Co., Pittsburgh, Pa. Res., 6118 Jackson St., Pittsburgh, Pa. Feb. 7, 1914.
- FELIX, SAMUEL, Dist. Mgr., Dravo-Doyle Co., 1934 Commercial Trust Bldg., Philadelphia, Pa. June 17, 1916.
- FERNALD, BENJ. G., Sales Mgr., Kerr Turbine Co., 30 Church St., New York City. Dec. 8, 1912.
- FIELD, CHAS., Salesman, United States Graphite Co., Saginaw, Mich., and 1058 Leader News Bldg., Cleveland, O. Res., 1506 Cohasset Ave., Lakewood, O. Dec. 8, 1911.
- FISHBACK, F. R., Dist. Mgr., The Electric Controller & Mfg. Co., Cleveland, O. Res., 2637 Exeter Road, Shaker Heights, Cleveland, O. April 4, 1912.
- FISKE, R. F., Salesman, Union Electric Co., 31 Terminal Way, Pittsburgh, Pa. Res., 1331 Beechview Ave., Beechview, Pa. Sept. 30, 1912.
- FLEISCHER, THOS. J., Salesman, Crouse-Hinds Co., 2302 Union Central Bldg., Cincinnati, O. Res., 14909 Clifton Blvd., Cleveland, O. Dec. 8, 1911.
- FONGER, A. D., Treas., General Devices & Fittings Co., 817 West Washington Boulevard, Chicago, Ill. Res., 540 North Harvey Ave., Oak Park, Ill. Oct. 1, 1912.
- FRANK, Dr. K. G., Representative Siemens & Halske, A. G., and Siemens Schuckertwerke, G.m.b.H., 90 West St., New York, N. Y. Res., Wyoming, N. J. Dec. 20, 1912.
- FRAWLEY, FRANK D., Salesman, Corliss Carbon Co., 355 People's Gas Bldg., Chicago, Ill. Oct. 3, 1914.
- FREEMAN, ROBERT F., Vice Pres. and Gen'l Mgr., Central States for American Conduit Co., 148th St. & Railroad Ave., East Chicago, Ind. Res., 4438 Olcott Ave. Jan. 15, 1912.
- FREYN, H. J., President, Heinrich J. Freyn, Inc., Engineers, 528 People's Gas. Bldg., Chicago, Ill. Res., 5201 Harper Ave. Nov. 18, 1916.
- FUNK, FRANK W., E. E., Mahoning & Shenango Ry. & Light Co., Youngstown, O. Mar. 18, 1916.

- GAGE, GORDON, Asst. Supt., Elect. Dept., American Rolling Mill Co., Middletown, O. Res., 617 Garfield Ave., Middletown, O. Feb. 7, 1914.
- GARDNER, JAS. W., Milwaukee, Wis. Jan. 15, 1912.
- GARNIER, EDWARD J., Asst. to Chf. Elec'n., Indiana Steel Co., Gary, Works, Gary, Ind. Res., 767 Madison St. Feb. 3, 1912.
- GILES, CHAS., Foreman, Elec. Dept., National Tube Co., McKeesport, Pa. Res., 820 Arlington Ave. March 17, 1917.
- GILLIE, H. C., Asst. Sales Mgr., Cleveland Electric Illuminating Co., 111 Illuminating Bldg., Cleveland, O. Dec. 18, 1915.
- GILLIS, GEO., Chf. Elec., Blast Fce. Dept., Pgh. Steel Co., Monessen, Pa. Res., 665 McKee St. June 5, 1915.
- GILPIN, CHAS. DAVYS, Elect. Eng'r., The Wellman-Seaver-Morgan Co., 70th and Central Ave., Cleveland, O. Res., 1833 E. 81st St. March 24, 1913.
- GLASGOW, WM. ROSS, Asst. Wks. Mgr., American Steel Foundries, Granite City, Ill. Res., 4918 McPherson Ave., St. Louis, Mo. Sept. 8, 1913.
- GLEDHILL, H. W., Sales Engr., Shepard Elec. Crane & Hoist Co., 801 Bulletin Bldg., Philadelphia, Pa. Res., 5642 Pine St. Apr. 15, 1916.
- GLOECKNER, R. D., Sales Mgr., V. V. Fittings Co., 42 E. Congress St., Detroit, Mich. Oct. 3, 1914.
- GOETZ, WERNER W., Sales Engr., The Cutler-Hammer Mfg. Co., Philadelphia, Pa. June 17, 1916.
- GREENFIELD, S., Salesman, Western Electric Co., 11th & York Sts., Philadelphia, Pa. Res., 4931 Knox St. Dec. 16, 1916.
- GREENLEAF, W. T., Sales Engr., Allis-Chalmers Mfg. Co., 1209 Park Bldg., Pittsburgh, Pa. Res., 6623 Ridgeville St. March 18, 1916.
- GREENWOOD, WALTER, Safety Engineer, Carnegie Steel Co., Ohio Works, Waverly Ave., Youngstown, O. Res., 1044 Orange St. Dec. 8, 1911.
- GRIGGS, ROBERT, Chf. Elect., Consolidated Wks., American Steel & Wire Co., Cleveland, O. July 11, 1916.
- HAESLER, W. E., V. P. & Elec. Supt., Berks Engineering Co., Reading, Pa. Res., 410 Douglass St., Reading, Pa. Feb. 17, 1917.
- HAFFNER, FRANK T., Sales Agt., Pass & Seymour, Inc., Solvay, N. Y. Res., Louisville, Ky. Oct. 3, 1914.
- HARE, B. T., Sales Mgr., Rumsey Electric Co., 1231 Arch St., Philadelphia, Pa. Res., 5370 Wingohocking Terrace. Nov. 18, 1916.
- HARNISCHFEGER, HENRY, Pres., Pawling & Harnischfeger Co., Milwaukee, Wis. Res., 3416 Grand Ave. Nov. 8, 1912.
- HARRISON, WARD, Illuminating Engineer, National Lamp Works, Nela Park, Cleveland, O. Res., 25 Page Ave., E. Cleveland, O. Dec. 8, 1911.

- HARRY, EDWARD W., E. E., National Tube Co., McKeesport, Pa. Res., 1201 Jenny Lind St. Feb. 17, 1917.
- HARVEY, JAS. G., Salesman, Westinghouse Lamp Co., 111 W. Washington St., Chicago, Ill. Res., 6009 St. Lawrence Ave. August 10, 1915.
- HAUSEN, RAYMOND F., Partner, Pittsburgh Carbon Brush Co., & R. F. Hausen & Co., 518 Sandusky St., N. S., Pittsburgh, Pa. Res., 1208 Esplanade St., N. S., Pittsburgh, Pa. Feb. 6, 1915.
- HAYES, JOHN P., Foreman, Crescent Elec. & Mfg. Co., Pittsburgh, Pa. Res., 121 Annabelle St., Pittsburgh, Pa. March 17, 1917.
- HERTZ, STANTON S., Sales Engr., Electrical Engineering & Mfg. Co., Farmers Bank Bldg., Pittsburgh, Pa. Res., 1110 Center St., Wilksburg, Pa. May 20, 1916.
- HEGERTY, P. F., Salesman, Westinghouse Electric & Mfg. Co., 1808 Union Bank Bldg., Pittsburgh, Pa. Res., 600 Hampton Place, Wilksburg, Pa. Feb. 7, 1914.
- HENCH, L. W., Power Sales Engr., M. & S. Ry. & Light Co., Youngstown, O. Dec. 16, 1916.
- HENDERSON, C. T., Eng'r., The Cutler-Hammer Mfg. Co., P. O. Box, 1564 Milwaukee, Wis. Res., 635 Farwell Ave. Jan. 15, 1912.
- HENRICKS, A. G., Asst. General Mgr., Pawling & Harnischfeger Co., Milwaukee, Wis. Res., 332 14th St. Oct. 10, 1913.
- HIPPLE, S. R., Mgr., Simplex Surface Contact Co., Williamsport, Pa. Oct. 9, 1915.
- HITCHCOCK, MORLEY H., Vice Pres. Reliance Electric & Engineering Co., Cleveland, O. Res., 2094 Cornell Road. Mar. 8, 1912.
- HOFF, LEIGH P., Salesman, Allis Chalmers Mfg. Co., 814 Frick Bldg., Pittsburgh, Pa. Feb. 6, 1915.
- HOMMEL, LUDWIG, Pres. Ludwig Hommel Co., 947 Penn Ave., Pittsburgh, Pa. Res., 606 S. Dallas Ave., E. E., Pgh. Feb. 1, 1912.
- HOPWOOD, J. M., Asst. Genl. Mgr., George J. Hagan Co., Peoples Bank Bldg., Pittsburgh, Pa. Res., 1679 Potomac Ave., Dormont, Pittsburgh, Pa. March 17, 1917.
- HORNE, G. R., Salesman, Cutter Electric Mfg. Co., 19th & Hamilton Ave., Philadelphia, Pa. Res., 2902 N. 26th St., Philadelphia, Pa. March 17, 1917.
- HORTON, B. D., Pres and Gen'l. Mgr., Detroit Fuse & Mfg. Co., 1400 Rivard St., Detroit, Mich. Res., 146 Calvert Ave. Feb. 3, 1912.
- HOVEY, ALFRED F., Mgr., Construction, Standard Underground Cable Co., 700 Westinghouse Bldg., Pittsburgh, Pa. Res., 6350 Aurelia St. June 5, 1915.
- HUEBNER, C. A., Salesman, Westinghouse Elect. & Mfg. Co., 1801 Union Bank Bldg., Pittsburgh, Pa. Res., 617 Foreland St., N. S., Pittsburgh, Pa. May 2, 1914.
- HUFF, ERNEST L., E. E., Pennsylvania Salt Mfg. Co., Natrona & Phila. Plants, Federal St., Natrona, Pa. Feb. 17, 1917.
- HULL, FLOYD B., Salesman, West. Elec. & Mfg. Co., 1803 Union Bank Bldg., Pittsburgh, Pa. Oct. 3, 1914.

- HUME, JNO. E. N., Com'l Engr., General Electric Co., Schenectady, N. Y. Res., 1202 Union St. Oct. 3, 1914.
- HUNT, FRED L., Elect. Eng'r., Carnegie Steel Co., Homestead Wks., Munhall, Pa. Res., 5500 Aylesboro Ave. Pittsburgh, Pa. Aug. 26, 1912.
- HURLBUT, F. P., N. Y. Mgr., Cleveland Crane & Engineering Co., 50 Church St., New York City. Res., 320 N. Y. Ave., Brooklyn, N. Y. Jan. 15, 1912.
- INGALLS, C. E., Salesman, Crocker-Wheeler Co., Oliver Bldg., Pittsburgh, Pa. Res., 6102 Walnut St., E. E. Mar. 18, 1916.
- IRELAND, J. MORRIS, Salesman, Westinghouse Elec. & Mfg. Co., 1114 Sweetland Bldg., Cleveland, O. Res., 2041 E. 96th St., Suite No. 27, Cleveland, O. Nov. 7, 1914.
- IREMONGER, R. S., Sales Engineer, Benjamin Electric & Mfg. Co., 114 Liberty St., New York City. Res., 47 Claremont Ave. Nov. 28, 1911.
- JACKSON, W. C., Sales Mgr. & V. P., Rowan Controller Co., Inc., 308 N. Holliday St., Baltimore, Md. Res., 4208 Main Ave. Sept. 9, 1916.
- JAMES, HENRY D., Div. Engr., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Res., 12 Trenton Ave., Swissvale, Pa. Dec. 16, 1916.
- JAMES, WM. F., Salesman, Westinghouse Electric & Mfg. Co., 1442 Widener Bldg., Philadelphia, Pa. Res., 227 East Mt. Pleasant Ave., Mt. Airy, Philadelphia, Pa. Dec. 8, 1911.
- JOHNSON, S. P., Chf. Elec., Niles-Bement-Pond Co., Bemont Works, 21st & Callowhill St., Philadelphia, Pa. March 17, 1917.
- JOHNSON, W. J., Dist. Mgr., Lidgerwood Mfg. Co., 1113-14 Union Bank Bldg., Pittsburgh, Pa. Res., Jefferson Apts., Louisa St. May 1, 1915.
- JONES, PAUL W., Sales Engr., Cutler-Hammer Mfg. Co., 1239 Gurdian Bldg. Res., 1954 E. 73rd St., Cleveland. May 20, 1916.
- JONES, WARNER, Cleveland, O. Res., 10018 N. Boulevard. Oct. 3, 1912.
- KAUFFMAN, RAY, Mgr. Industrial Dept., The Erner Electrical Co., St. Clair Ave. & E. 2nd St., Cleveland, O. Res., 10011 Ostend Ave. May 13, 1912.
- KACIN, B. G., Sales Engr., Central Electric Co., 320-326 S. 5th Ave., Chicago, Ill. Sept. 18, 1916.
- KELLER, ARTHUR, Electrical Eng'r., Pawling & Harnischfeger Co., Milwaukee, Wis. Res., 464 Marshall St. Dec. 8, 1911.
- KELLY, CORNELIUS J., Elec. Foreman, Midvale Steel Co., Philadelphia, Pa. Res., 48 W. Rockland St., Germantown, Pa. Feb. 17, 1917.
- KENNEDY, E. E., 29 Harrison St., Munhall, Pa. May 1, 1915.
- KENNEDY, J. O., Gen'l. Mgr., The Massillon Electric & Gas Co., Massillon, O. Res., 1127 Wellman St. June 17, 1916.

- KENNEDY, JOS. W.**, Eng'r., care Julian Kennedy, Bessemer Bldg., Pittsburgh, Pa. Res., 5711 Northumberland Ave., Pittsburgh, Pa. Aug. 25, 1913.
- KIEHL, EUGENE P.**, Supt. Power Dept., Atlantic Refining Co., Philadelphia, Pa. Res., Oak Lane. Nov. 18, 1916.
- KILNER, RALPH H.**, Salesman, Westinghouse Electric & Mfg. Co., 39 S. LaSalle St., Chicago, Ill. Res. 4721 Malden St. Dec. 8, 1911.
- KIRKLAND, H. B.**, V. P. & Genl. Sales Mgr., The American Conduit Mfg. Co., Keystone Bldg., Pittsburgh, Pa. Res., Bellefield Dwelling. Nov. 13, 1915.
- KNAPP, M. F.**, 5715 Elmer St., E. E., Pittsburgh, Pa. Oct. 3, 1914.
- KNIGHT, CHAS. D.**, Managing Eng'r., Industrial Control Department, General Electric Co., Schenectady, N. Y. Res., 3 Lowell Road. Jan. 6, 1912.
- KNOX, E. E.**, Manager Bury Compressor Co., 701 Empire Bldg., Pittsburgh, Pa. Feb. 17, 1917.
- KODJBANOFF, BASIL G.**, Mgr., Benjamin Electric Mfg. Co., 114 Liberty St., New York, N. Y. Nov. 23, 1911.
- KOEHLER, A. T.**, Sales Engr., Westinghouse Electric & Mfg. Co., 1801 Union Bank Bldg., Pittsburgh, Pa. Res., 630 Lennox Ave., Wilkesburg, Pa. Sept. 18, 1916.
- LAVINE, SAUL**, Sales Agt., General Electric Co., Oliver Bldg., Pittsburgh, Pa. Res., 6428 Darlington Road. Dec. 26, 1911.
- LEIGHTON, W. P.**, Sales Dept., The Morgan Engineering Co., Alliance, O. Res., R. F. D. No. 1. June 17, 1916.
- LEITHOLD, HARRY W.**, Elect. Salesman, Mgr. of Motor Dept., Novelty Electric Co., 50 N. 4th St., Philadelphia, Pa. Res., 5901 Carpenter St. Jan. 20, 1917.
- LEMON, HERBERT R.**, Lamp Specialist, Western Electric Co., 413 Huron Road, Cleveland, O. May 20, 1916.
- LE NOIR, EUGENE T.**, Philadelphia Rep., Union Electric Mfg. Co., Roller Smith Co., Monitor Controller Co., 963 Drexel Bldg., Philadelphia, Pa. Res., 110 S 51st St. March 17, 1917.
- LENT, WILMAR F.**, Sales Engr., Cutler Hammer Mfg. Co., 1201 Chestnut St., Philadelphia, Pa. Feb. 17, 1917.
- LEPPER, O. R.**, Salesman, Western Electric Co., Box 42, Pittsburgh, Pa. Res., 2838 Broadway Ave., Dormont, Pittsburgh, Pa. June 5, 1915.
- LEWIS, JOHN R.**, Salesman, Crocker-Wheeler Co., 2132 Oliver Bldg., Pittsburgh, Pa. June 17, 1916.
- LINCOLN, E. S.**, Pres. & Chf. Engr., E. S. Lincoln, Inc., 25 Silver St., Waterville, Me. Res., Winter St. June 5, 1915.
- LINDBERG, EDW. F. J.**, Chicago Mgr., Reliance Electric & Engr. Co., 705 Fisher Bldg., Chicago, Ill. Res., 3435 Dearborn St., Chicago, Ill. Oct. 1, 1912.

- LINDSTROM, G., Chf. Engr., Electric Products Co., 1067 E. 152nd St., Cleveland, O. Res., Willoughby, O. May 20, 1916.
- LOUNSBERY, GEO. H., Salesman, Western Electric Co., 500 So. Clinton St., Chicago, Ill. Res., Riverside, Ill. Sept. 18, 1916.
- LUDWICK, R. E., Sales Mgr., Cleveland Crane & Engineering Co., Wickliffe, O. Res., 1665 E. 73rd St., Cleveland, O. June 13, 1912.
- LUM, W. O., V. P. & Engr., Gould Motor Parts Co., York, Pa. Aug. 12, 1914.
- LYNDE, C. C., Engineering Editor, "The Blast Furnace & Steel Plant" and "Steel and Iron." P. O. Box, 468, Pittsburgh, Pa. Res., 3400 Schaffer Place., Mt. Lebanon. Nov. 13, 1915.
- LYTLE, JOHN H., Supt. Accessories Dept., Standard Underground Cable Co., 700 Westinghouse Bldg., Pittsburgh, Pa. Res., 308 Breeding Ave., Ben Avon, Pittsburgh, Pa. June 5, 1915.
- MAIR, J. E., Sales Mgr., The Brunt Tile & Porcelain Co., 403 May Bldg., Pittsburgh, Pa. Oct. 3, 1914.
- MAGUIRE, THOS., Electric Foreman, Midvale Steel Co., Philadelphia, Pa. Res., 1610 Staub St., Nicetown, Pa. Feb. 17, 1917.
- MALONEY, C. J., Sales Engr., Cutler-Hammer Mfg. Co., 50 Church St., New York City. Res., 23 Cambridge St., E. Orange, N. J. June 17, 1916.
- MARKS, W. M., Sales Engr., Western Electric Co., 910 River Ave., N. S., Pittsburgh, Pa. Res., 311 Penn Ave., Wilksburg, Pa. Jan. 15, 1912.
- MARSHALL, EDW. C., Sales Eng'r., General Electric Co., 1315 H. W. Oliver Bldg., Pittsburgh, Pa. Res., 1139 Peermont Ave., Dor-mont. Mar. 18, 1916.
- MARTIGNONE, D., Gen'l. Sales Eng'r., General Electric Co., 1008 Illuminating Bldg., Cleveland, O. Res., 1616 E. 86th St. Cleve-land, O. Dec. 26, 1911.
- MAY, FRANK P., Asst. Supt., Elec. Dept., Carnegie Steel Co., Mingo Junction, O. Res., 305 Ross St., Steubenville, O. Feb. 6, 1915.
- MENISH, J. R., M. E., Keystone Lubricating Co., 21st & Clearfield St., Philadelphia, Pa. June 17, 1916.
- MERRILL, A. S., Salesman, Chicago Fuse Mfg. Co., 1014 W. Congress St., Chicago, Ill. Oct. 3, 1914.
- MILLER, GREY E., Engineering Salesman, Westinghouse Electric & Mfg. Co., 1801 Union Bank Bldg., Pittsburgh, Pa. Res., 447 Ella St., Wilksburg, Pa. Apr. 15, 1916.
- MILLER, H. H., Salesman, Doubleday Hill Elect. Co., 719 Liberty St., Pittsburgh, Pa. Feb. 17, 1917.
- MILLS, E. D., Chf. Chemist & Metallurgist, the Joyce-Cridland Co., Dayton, O. Home address, Box. 365. July 10, 1915.
- MILLS, GEO. P., Sales Agt., General Electric Co., Witherspoon Bldg., Philadelphia, Pa. Res., 6044 Pine St. Jan. 20, 1917.
- MILNER, CHAS., Elect. Foreman, Midvale Steel Co., Philadelphia, Pa. Res., 5920 Beechwood St., Germantown, Pa. Feb. 17, 1917.

- MINIER, W. C., Dist. Mgr., Shepard Elect. Crane & Hoist Co., 1212 Benedum-Trees Bldg., Pittsburgh, Pa. Res., 335 Millvale Ave., Pittsburgh, Pa. May 2, 1914.
- MONTGOMERY, A. G., Asst. in Dist. Steam Eng. Dept., American Steel & Wire Co., Pittsburgh, Pa. Res., 723 Wallace Ave. Sept. 18, 1916.
- MONTGOMERY, L. S., Dist. Sales Mgr. Res., 138 Bidwell Parkway, Buffalo, N. Y. June 6, 1913.
- MOORE, ROBT. H., Division Mgr., Sales Dept., West. Elec. & Mfg. Co., 2133 Conway Bldg., Chicago, Ill. Res., 1456 Fargo Ave., Wilmette, Ill. Oct. 3, 1914.
- MORAN, H. C., National Metal Molding Co., 1110 Fulton Bldg., Pittsburgh, Pa. August 10, 1915.
- MOREY, LEONARD, Sales Engr., Electric Products Co., Cleveland, O. March 17, 1917.
- MORGAN, JOHN B., Chf. Elec. & M. M., Wm. B. Pollock Co., Youngstown, O. Res., 1620 Charlotte Ave. May 1, 1915.
- MORRIS, A. F., Sales Mgr., The Morgan Engineering Co., Alliance, O. Res., 611 South Union Ave. Jan. 15, 1912.
- MORROW, LINN O., Sales Eng'r., Cutter Elect. & Mfg. Co., 19th & Hamilton Sts., Philadelphia, Pa. Res., 4502 N. 7th St. May 20, 1916.
- MOTZ, J. F., Dist. Mgr., The Electric Controller & Mfg. Co., 1539 Oliver Bldg., Pittsburgh, Pa. Res., 6 Buffalo St. Dec. 8, 1911.
- MUIR, TOM J., Sales Eng'r., Morgan Engineering Co., Alliance O. Res., 729 Keplinger Ave. June 5, 1915.
- MULLHAUPT, ALFRED, Mgr., Corliss Carbon Co., Bradford, Pa. Res., 25 School St., Bradford, Pa. Oct. 3, 1914.
- MUNDO, C. J., Salesman, General Electric Co., 1314 Oliver Bldg., Pittsburgh, Pa. Res., 5733 Forbes St. Jan. 6, 1912.
- MURPHY, EDWIN J., Designing Engr., General Electric Co., Schenectady, N. Y. Res., 41 Ray St., R. F. D. No. 1. Oct. 9, 1915.
- MacCUTCHEON, A. M., Designing Engr., Reliance Electric & Engineering Co., Cleveland, O. Res., 61 Page Ave. Jan. 20, 1917.
- MacGUYER, H. F., Spec'l Representative, D. & W. Fuse Co., Providence, R. I. Res., Laurel Beach, Milford, Conn. Oct. 3, 1914.
- MacVAUGH, HERBERT W., Pgh. Sales Mgr., The Cutter Electric & Mfg. Co., Park Bldg., Pgh. Pa. Res., 7914 Inglenook Place Wilksburg, Pa. Dec. 8, 1911.
- McAULEY, ARTHUR W., Shop Foreman, Edgewater Steel Co., Oakmont, Pa. Res., 322 Oakmont Ave. June 5, 1915.
- McCOMBS, W. A., Pres., W. A. McCombs Co., First National Bank Bldg., Pittsburgh, Pa. Res., 3807 California Ave., N. S. Feb. 19, 1916.
- McDOWELL, F. H., Salesman, National Carbon Co., 511 Park Bldg., Pittsburgh, Pa. Res., 1496 Alameda, Lakewood, O. Dec. 17, 1911.

- McGRAIL, M. E., Sales Rep., Westinghouse Electric & Mfg. Co., 1114 Sweetland Bldg., Cleveland, O. Res., 2073 E. 79th St. Sept. 5, 1914.
- McINTYRE, L. W., Salesman, Keystone Lubricating Co., 309 W. Fairmont Ave., Pittsburgh, Pa. March 17, 1917.
- McKEE, F. E., Asst. to Pres., Manning Maxwell & Moore Co., 19 West 40th St., New York City. Dec. 8, 1911.
- McKEE, FRANK W., Engr., General Electric Co., Oliver Bldg., Pittsburgh, Pa. Res., 499 East End Ave., Beaver, Pa. Apr. 26, 1907.
- McKELVEY, A. B. Salesman, Westinghouse Elect. & Mfg. Co., 1804 Union Bank Bldg., Pittsburgh, Pa. Res., 1315 Lincoln Ave., E. E. April 4, 1914.
- McKINLEY, JOS., Mgr. of Power Sales, Duquesne Light Co., 435 Sixth Ave., Pittsburgh, Pa. Dec. 18, 1915.
- McLAIN, R. H., Engr., P. & M. Dept., Genl. Elec. Co., Schenectady, N. Y. Res., 111 Wendell Ave. Dec. 16, 1916.
- McNEELY, JAS. G., Lighting Specialist, Western Elect. Co., 910 River Ave., N. S., Pittsburgh, Pa. Dec. 18, 1915.
- McQUILLEN, J. J., Pgh. Rep., The Morgan Engineering Co., 1216 Oliver Bldg., Pittsburgh, Pa. Res., 703 Arch St., N. S. Dec. 8, 1911.
- McTAMNEY, JOHN, Elec. Foreman, Midvale Steel Co., Philadelphia, Pa. Res., 3727 N. Percy St., Nicetown, Pa. Feb. 17, 1917.
- NOERAGER, ARTHUR J., Chf. Elect'n., Braden Copper Co., Rancagua, Chile, S. A. Jan. 15, 1916.
- OETERS, EDGAR O., Mfrs. Agt., Machinery Exhibiting Dept., The Bourse, Phila., Pa. March 17, 1917.
- OURBACKER, S. H., Salesman, Westinghouse Electric & Mfg. Co., Widener Bldg., Philadelphia, Pa. Res., 5033 Springfield St., West Philadelphia, Pa. Nov. 18, 1916.
- PATERACKI, R. M., Rep. Salesman., V. V. Fittings Co., 39 Cortlandt St., New York City. Res., 343 Bouquet St., Pittsburgh, Pa. Sept. 8, 1915.
- PAULY, KARL A., Elect. Eng'r., P. & M. Dept., General Electric Co., Schenectady, N. Y. Res., 10 Parkwood Blvd. Jan. 15, 1912.
- PENDELTON, D. D., Dist. Sales Mgr., Wheeler Condenser & Engineering Co., 1635 H. W. Oliver Bldg., Pittsburgh, Pa. Feb. 19, 1916.
- PETTIBONE, C. E., Safety Inspector, Pickands, Mather & Co., 202 Western Reserve Bldg., Cleveland, O. Res., 1224 Marlow Ave., Lakewood, O. Dec. 24, 1912.
- PAYNER, JAS. M., Coml. Engr., General Electric Co., Lexington St. Bldg., Baltimore, Md. Res., 3306 Wallbrook Ave. Dec. 16, 1916.
- PHILLIPS, CHAS. O., Elect. Foreman, Midvale Steel Co., Philadelphia, Pa. Res., 5141 Germantown Ave. Feb. 17, 1917.
- PHILLIPS, R. M., Sales Rep., Electric Controller & Mfg. Co., 623 Monadnock Bldg., Chicago, Ill. Res., 4720 Michigan Boulevard. Sept. 18, 1916.

- PIERCE, A. G., Dist. Mgr., Cutler-Hammer Mfg. Co., 2211 Farmers Bank Bldg., Pittsburgh, Pa. Res., 394 Center St., Wilkinsburg, Pa. May 2, 1914.
- PIPER, ALFRED H., Dist. Rep., Electric Controller & Mfg. Co., 302 Lincoln Inn Court Bldg., Cincinnati, O. Res., 2308 Monroe Ave., Norwood, O. April 15, 1916.
- PIRTLE, CLAIBORNE, Pres., The Electric Controller & Mfg. Co., 2698 E. 79th St., Cleveland, O. Res., 1864 East 97th St. Dec. 17, 1911.
- POWELL, W. H., Elect. Eng'r. in charge D. C. Dept., Allis-Chalmers Co., Milwaukee, Wis. Res., 2508 Grand Ave. Feb. 15, 1912.
- POYNTON, W. P., Electrical Eng'r., Le Carbone Carbon Brush Co., 634 Wabash Bldg., Pittsburgh, Pa. Res., 117 Lincoln Ave., Edgewood Park, Pa. Oct. 7, 1912.
- PRATT, HARLAN A., Mgr., Ind. & Power Div., Westinghouse Electric & Mfg. Co., 165 Broadway, N. Y. Res., 25 Hillyar St., East Orange, N. J. Jan. 20, 1913.
- PRICE, WALTER, Eastern Sales Mgr., Pawling & Harnischfeger Co., 50 Church St. & Stephen Girard Bldg., Philadelphia, Pa. Jan. 20, 1917.
- PROVOST, GEO. W., President, Union Electric Co., Pittsburgh, Pa. Res., 5808 Beacon St. Dec. 8, 1911.
- PURCELL, W. H., Pres. and Gen'l. Mgr., The Alliance Machine Co., Mahoning Ave., Alliance, O. Res., 145 S. Linden Ave. Dec. 8, 1911.
- RATH, JAS. M., Electrical Foreman, Natl. Tube Co., McKeesport, Pa. Res., 1010 McCleary St. Feb. 17, 1917.
- RATHBONE, RICHMOND L., Sales Rep., Westinghouse Electric & Mfg. Co., 1114 Sweetland Bldg., Cleveland, O. Feb. 21, 1912.
- RAY, J. L., Sales Mgr., Western Electric Co. Box, 42, Pittsburgh, Pa. Res., 825 Braddock Ave. June 5, 1915.
- REI, HARRY D., Salesman, Crouse Hinds Co., Syracuse, N. Y. Res., 89 Knox Ave., Mt. Oliver, Pittsburgh, Pa. Oct. 3, 1914.
- REYNOLDS, BAXTER, Dist. Mgr., Burke Electric Co., Land Title Bldg., Philadelphia, Pa. Sept. 7, 1916.
- RICE, HERBERT, Gen'l. Sales Mgr., The Cutter Electric & Mfg. Co., 19th and Hamilton Sts., Philadelphia, Pa. Dec. 8, 1911.
- RICHARDSON, HARRY S., Sales Eng'r., Electric Controller & Mfg. Co., 2698 E. 79th St., Cleveland, O. Res., 3063 Edgehill Rd., Cleveland Heights, O. Feb. 7, 1914.
- RIGBY, GEO. A., M. M., New Castle Works, Carnegie Steel Co., George St., New Castle, Pa. Res., 307 Leasure Ave., New Castle, Pa. May 2, 1914.
- RILING, F. E., Salesman, Harvey Hubbell, Inc., 4510 Chestnut St., Philadelphia, Pa. Feb. 17, 1917.
- RIPLEY, C. S., Mgr., Roller-Smith Co., 711 Williamson Bldg., Cleveland, O. Res., 2221 Cummington Rd. Oct. 3, 1914.

- ROBBINS, C. C., Sec. & Gen'l. Mgr., The Cleveland Crane & Eng. Co., Wickliffe, O. Feb. 7, 1914.
- ROBBINS, WALTER, Vice President, Wagner Electric Mfg. Co., 6400 Plymouth Ave., St. Louis, Mo. Res., 4376 Westminster Place. Dec. 8, 1911.
- ROBERTS, ALVIN LEWIS, Designing Engr., Bethlehem Steel Co., South Bethlehem, Pa. Res., 75 Church St., Bethlehem, Pa. Oct. 4, 1912.
- ROE, JULIAN, District Mgr., Crocker-Wheeler Co., Old Colony Bldg., Chicago, Ill. Res., 4712 Ellis Ave. Dec. 17, 1912.
- ROSE, W. J., Gen'l. Mgr., Alliance Gas & Power Co., Alliance, O. May 20, 1916.
- ROSS, ALEXANDER R., Com'l. Engr., Westinghouse Lamp Co., 1415 Union Bank Bldg., Pittsburgh, Pa. Res., 421 Orchard Avenue. Sept. 8, 1915.
- ROWAN, JOHN S., Pres., Rowan Elect. Mfg. Co., 308 N. Holliday St., Baltimore, Md. Oct. 21, 1916.
- RUDDIMAN, JOHN, Vice Pres., Isley-Doubleday & Co., 229 Front St., New York City. Res., Hastings on Hudson. Dec. 8, 1911.
- RUMSEY, GEO. A., Secy. & Treas., Rumsey Electric Co., 1231 Arch St., Philadelphia, Pa. Res., 732 Vernon Road. Dec. 16, 1916.
- RUNNER, W. R., Genl. Engr. Div., Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa. Res., 516 Mifflin St., Wilkinsburg, Pa. Jan. 20, 1917.
- RUSH, RALPH M., Dist. Mgr., Kerr Turbine Co. and The Falk Co., 2201 Oliver Bldg., Pittsburgh, Pa. Res., Marlborough Apts., Darraugh St. Sept. 10, 1913.
- RUSHMORE, DAVID B., Chief Eng'r. Power & Mining Dept., General Electric Co., Schenectady, N. Y. Res., 234 Union St. Dec. 8, 1911.
- RUSSELL, S., Jr., Dist. Mgr., Crocker-Wheeler Co., 1315 N. American Bldg., Philadelphia, Pa. Res., 242 W. Johnson St., Germantown, Pa. Sept. 26, 1912.
- RUTH, R. H., Dist. Mgr., Benjamin Electric Mfg. Co., Box 807, Pittsburgh, Pa. Res., Mt. Lebanon, Pa. March 11, 1912.
- RUTHERFORD, B., Consulting Engr., 200 Ninth St., Pittsburgh, Pa. Res., 5852 Douglas Ave. April 15, 1916.
- RYAN, E. C., Representative, Elect. Controller & Mfg. Co., 50 Church St., New York, N. Y. Res., Pemelton Apt., B 4, Philadelphia, Pa. June 17, 1916.
- RYDE, HERBERT H., Chf. Engr.' Page Woven Wire Fence Co., Monessen, Pa. Res., 40 McKee Ave. May 20, 1916.
- SAGE, HENRY J., Kerr Turbine Co., Eng'r. Dept., 79 Milk St., Boston, Mass. Dec. 8, 1911.
- SCHAUMBERG, OTTO, Electrical Engr. & Salesman, Westinghouse Electric & Mfg. Co., 1801 Union Bank Bldg., Pittsburgh, Pa. Res., 5810 Kentucky Ave. Dec. 8, 1911.

- VON SCHLEGELL, FREDERICK, Dist. Mgr., Allis Chalmers Co., 2020 Peoples Gas Bldg., Chicago, Ill. Dec. 16, 1916.
- SCHULTZ, H. A., Chf. Safety Inspector, American Steel & Wire Co., 828 Frick Bldg., Pittsburgh, Pa. Res., 6615 Aylesboro Ave. July 25, 1913.
- SCHUSTER, C., Pres. & Genl. Mgr., Pittsburgh Electrical & Machine Works, Pittsburgh, Pa. Res., 521 Orchard St., Bellevue, Pa. March 17, 1917.
- SCHWARZ, FRED J., E. E., General Electric Co., P. & M. Engr. Dept., Schenectady, N. Y. Res., Ballston Spa, N. Y. Jan. 20, 1917.
- SCOTT, WM. M., Eng'r. and Gen'l. Mgr., The Cutter Electric & Mfg. Co., 19th and Hamilton Sts., Philadelphia, Pa. Dec. 8, 1911.
- SCOVEL, R. E., E. E., Steam Engineering Dept., American Steel & Wire Co., Cleveland, O. Res., 1530 E. 84th St. May 1, 1915.
- SEBRING, J. B., Rep. Pgh. Dist., The Esterline Co., Ward Leonard Electric Co., Monitor Controller Co., Baum and Euclid Sts., Pittsburgh, Pa. Res., 219 Ross Ave., Wilksburg, Pa. May 2, 1914.
- SELDOMRIDGE, WM. H., Elect. Foreman, Midvale Steel Co., Philadelphia, Pa. Res., 1310 N. Frazier St., W. Phila., Pa. Feb. 17, 1917.
- SELIG, ERNEST T., Commercial Eng'r., United Gas & Elec. Eng'r Corp., 61 Broadway, New York. Res., 920 N 16th St., Harrisburg, Pa. Jan 9, 1915.
- SELLERS, STEEL R., Sales Specialist, Western Elec. Co., Inc., River Ave., Pittsburgh, Pa. Res., 218 Princeton Ave., Bellevue, Pgh.. Pa. Jan. 20, 1917.
- SEMPLE, F. H., Sales Engr., Fairbanks Morse Co., 900 Wabash Ave., Chicago, Ill. Res., 4119 Kenmore Ave., Chicago, Ill. July 11, 1914.
- SHALLING, HENRY W., Illuminating Eng'r., Ivanhoe Dept., Nela Park Works, General Electric Co., Cleveland, O. Res., 84 Marloes Ave. March 18, 1916.
- SHEPPERD, WM. B., General Foreman, Elect. Dept., National Tube Co., McKeesport, Pa. Res., 718 Federal St. Feb. 17, 1917.
- SHERMAN, JOHN, Repr., American Conduit, Adams Bagnall Co., 800 Widener Bldg., Philadelphia, Pa. Res., 422 W. Coulter St. Dec. 16, 1916.
- SINGER, FRANK P., 717 Western Ave., Toledo, O. July 25, 1916.
- SINGLETON, J. O., Trav. Repr., H. & H. Co. & H. T. Paiste Co., Hotel Covington, 37 & Chestnut St., Philadelphia, Pa. Res., 60 Harrison Ave., Braintree, Mass. Oct. 21, 1916.
- SKEWIS, WM. H., Draftsman, Elec. Dept., Pittsburgh Crucible Steel Co., Midland, Pa. March 17, 1917.
- SLATER, ADAM, Safety Inspector, Carnegie Steel Co., Pittsburgh, Pa. Res., 608 13th St., Munhall, Pa. Sept. 7, 1913.

- SLOCUM, G. FRANK, Asst. Sec'y., Doubleday-Hill Electric Co., 719-721 Liberty St., Pittsburgh, Pa. Res., 8 Brushton Ave. Dec. 8, 1911.
- SMITH, FRANK, Asst. Mgr., Otis Elevator Co., 1200 Keenan Bldg., Pittsburgh, Pa. Res., 519 Coal St., Wilkinsburg, Pa. April 4, 1914.
- SOFFE, WM. W., Sales Engr., Harter Mfg. Co., 1132-6 W. Austin Ave., Chicago, Ill. Res., 4113 W. Congress St. Sept. 8, 1915.
- SPELLMIRE, W. B., Sales Mgr., General Electric Co., Oliver Bldg., Pittsburgh, Pa. Res., University Club. April 30, 1912.
- STACK, G. E., E. E., Industrial Control Engr. Dept., General Electric Co., Schenectady, N. Y. Res., Ballston Spa., R. D. 5, New York Jan. 20, 1917.
- STAMBAUGH, PAUL H., Power Sales Engr., Mahoning & Shenango Ry. & Lt. Co., Youngstown, O. Res., Box 58. March 18, 1916.
- STANDING, ALFRED J., Asst. Supt. of Elect. Dept., Bethlehem Steel Co., So. Bethlehem, Pa. Res., 126 N. 7th Ave., West Bethlehem, Pa. Aug. 12, 1914.
- STARBUCK, D. K., Sales Agt. in charge Youngstown Office, General Electric Co., 706 Stambaugh Bldg., Youngstown, O. Res., 1511 Elm. St. June 7, 1914.
- STARR, ARTHUR B., Power Salesman, Duquesne Light Co., 435 Sixth Ave., Pittsburgh, Pa. Res., 518 Academy Ave., Sewickley, Pa. Dec. 18, 1915.
- STEELE, H. G., Sec'y. and Treas., Pittsburgh Transformer Co., Preble Ave. and Adams St., Pittsburgh, Pa. Res., 1106 Pemberton St., N. S., Pittsburgh, Pa. Dec. 8, 1911.
- STEELE, W. D., Vice Pres., Benjamin Electric Mfg. Co., 120 S. Sangamon St., Chicago, Ill. Res., 1121 Chestnut Ave., Wilmette, Ill. Dec. 8, 1911.
- STEVENS, A. C., Sales Mgr., Cutler Hammer Mfg. Co., Milwaukee, Wis. March 17, 1917.
- STEVENSON, BARTON, Mgr. Power Div., Westinghouse Electric & Manufacturing Co., 1804 Union Bank Bldg., Pittsburgh, Pa. Res., 5548 Darlington Ave. Feb. 21, 1912.
- STEVENSON, P. V., Pgh. Res. Mgr., Morse Chain Co., Westinghouse Bldg., Pgh. Pa. Res., 7124 Meade St. Jan. 6, 1912.
- STEVENSON, WALTER E., Salesman, Westinghouse Electric & Mfg. Co., 1804 Union Bank Bldg., Pittsburgh, Pa. Res., 129 N. Linden Ave. Jan. 6, 1912.
- STEVENSON, WM. D., Rep., LeValley Vitae Carbon Brush Co., Westinghouse Bldg., Pgh., Pa. Res., 7026 Thomas Blvd. Jan. 6, 1912.
- STICKLE, E. S., Salesman, Western Electric Co., Box 42, Pittsburgh, Pa. Res., 1709 Baltimore St., Beechview. June 5, 1915.
- STICKNEY, G. H., Asst. to Mgr. of Incandescent Lamp Sales, General Electric Co., Sussex & 4th Sts., Harrison, N. J. Res., 5 Clairmont Place, Montclair, N. J. Dec. 8, 1912.

- STOIBER, GEO. W., Salesman, Van Dorn Electric Tool Co., Cleveland, O. Res., 514 E 117th St. Sept. 8, 1915.
- STOLTZ, G. E., Industrial Engineer, Westinghouse Elec. & Mfg. Co., General Engineering Division, East Pittsburgh, Pa. Res., 514 Trenton Ave., Wilkinsburg, Pa. April 10, 1915.
- STONE, D. M., Salesman, Detroit Fuse & Mfg. Co., 1214 Hilldale Ave., Pittsburgh, Pa. Res., Elberon Apts., Friendship & Winbiddle Aves., Pittsburgh, Pa. March 18, 1916.
- STONE, HERBERT W., JR., Power Engr., Poole Engr. & Mch. Co., Woodberry, Md. March 17, 1917.
- STRATTON, H. F., Gen'l. Mgr. and Chf. Eng'r., Electric Controller & Mfg. Co., Cleveland, O. April 22, 1912.
- SULLIVAN, WM. F., Assistant Mgr., Crocker-Wheeler Co., Old Colony Bldg., Chicago, Ill. Res., 4624 N. Manchester Ave. June 5, 1915.
- SWARTZ, ALFRED H., Traveling Salesman, Westinghouse Electric & Mfg. Co., 1808 Union Bank Bldg., Pittsburgh, Pa. Res., 10704 Churchill Ave., Cleveland, O. Feb. 14, 1912.
- SWARTZ, C. A., Salesman, Ludwig-Hommel & Co., 947 Penn Ave. Pittsburgh, Pa. Res., 909 Adelaide St., E. E. Feb. 19, 1916.
- SWINDELL, HARRY, District Mgr., Cleveland Office Holophane Works, Room 219, 6523 Euclid Ave., Cleveland, O. Oct 3, 1914.
- SYKES, WILFRED, General Eng'r., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Res., 5543 Raleigh St., E. E., Pittsburgh, Pa. Oct. 1, 1912.
- TAVEY, R. W., Lighting Specialist, Western Electric Co., Inc., Philadelphia, Pa. Res., 7125 Cresheim Rd., Mt. Airy, Phila. Jan. 20, 1917.
- TAYLOR, CLARENCE L., Chf. Eng'r., The Morgan Engineering Co., Alliance, O. Res., 653 S. Union Ave. April 25, 1911.
- THOMPSON, ALLISON J., Pres., The Thompson Electric Co., 5606 Euclid Ave., Cleveland, O. Res., 2612 Mayfield Road. Dec. 8, 1911.
- THOMPSON, HUGH L., Consulting Eng'r., 57 N. Main St., Waterbury, Conn. Oct. 17, 1913.
- TIPPINS, L. H., Power Salesman, Duquesne Light Co., 435 Sixth Ave., Pittsburgh, Pa. Res., King Edw. Apts., 201 Melwood Ave. Jan. 15, 1916.
- TORREY, C. E., Asst. Gen. Mgr., Canton Electric Co., Canton, O. May 20, 1916.
- TOWNSEND, F. P., Sales Engr., The Cutler-Hammer Mfg. Co., Milwaukee, Wis. Res., 528 Stowell Ave. Apr. 26, 1907.
- TREAT, ROBERT B., Direct Current Eng'r., The Crocker-Wheeler Co., Ampere, N. J. Res., 22 Vernon Place, East Orange, N. J. Jan. 6, 1912.
- TREGENZA, A. E., Gen'l. Sales Mgr., Economy Fuse & Mfg. Co., Kinzie & Orleans Sts., Chicago, Ill. Res., 5241 Magnolia Ave. Oct. 3, 1914.

- TRESSELT, F, Salesman, V. V. Fittings Co., 39 Cortlandt St., New York, N. Y. Res., 58 Rutgers Place, Passaic, N. J. Sept. 11, 1912.
- TUCKER, CHAS. H., Chief Eng'r., Toledo Bridge & Crane Co., Toledo, O. Res., 2625 Cherry St. Sept. 9, 1912.
- UEBELACKER, CHAS., Member of Firm, Ford, Bacon & Davis, 115 Broadway, New York City. Res., 267 Summitt Ave., Hackensack, N. J. Sept. 7, 1916.
- UPP, EDWIN L., Foreman Elect. Dept., Natl. Tube Co., Lorain, O. Res., 2141 E. 31st St. July 25, 1916.
- VAN KIRK, E. P., Elect. Eng'r., Westinghouse Air Brake Co., Wilmerding, Pa. Res., Elizabeth, Pa. Sept. 5, 1914.
- WADD, R. J., Sales Engr., Shepard Electric Crane & Hoist Co., 1212 Benedum Trees Bldg., Pittsburgh, Pa. Res., 528 McCormick Ave. Jan. 20, 1917.
- WARD, G. B., Salesman, Rumsey Electric Co., 1231 Arch St., Philadelphia, Pa. Res., 1304 Erie St. Nov. 18, 1916.
- WATSON, H. E., Sales Eng'r., Cent. District, Benjamin Electric Mfg. Co., 120 S. Sangamon St., Chicago, Ill. Res., 1312 E. 54th St. Aug. 21, 1912.
- WHITING, M. A., Elect. Eng'r., Power & Mining Dept., General Electric Co., Schenectady, N. Y. Res., Eastern and Earl Aves. Feb. 3, 1912.
- WIDDOWS, R. G., Dist. Mgr., The Electric Controller & Mfg. Co., 50 Church St., New York, N. Y. Res., 86 S. Park Way, East Orange, N. J. Dec. 8, 1911.
- WILEY, BRENT, Com'l. Eng'r., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Res., 5806 Howe St., Pittsburgh, Pa. Dec. 26, 1911.
- WILLIAMS, C. H., Industrial Control Spec., General Elec. Co., 414 S. Broad St., Philadelphia, Pa. Feb. 17, 1917.
- WILLIAMS, W. H., Dist Mgr., The Electric Controller & Mfg. Co., 53 W. Jackson St., Chicago, Ill. Res., 856 Leland Ave. Feb. 1, 1912.
- WILSON, J. R., Sales Mgr., Crocker-Wheeler Co., Ampere, N. J. Res., 18 Chelsea Place, East Orange, N. J. Dec. 8, 1911.
- WRAY, WILLIAM, Mgr. Pittsburgh Office, Allis Chalmers Co., 1209 Park Bldg., Pittsburgh, Pa. Feb. 19, 1916.
- WRIGHT, J. DAVID., Elect. Eng'r., Power & Mining Dept., General Elect. Co., Schenectady. N. Y. Res. 1 Ardsley Road, Schenectady, N. Y. July 11, 1914.
- YOUNG, F. C., Industrial Rep., Westinghouse Traction Brake Co., 318 Westinghouse Bldg., Pittsburgh, Pa. Res., 1314 Woodlawn Ave., Wilksburg, Pa. July 10, 1915.
- YOUNG, R. J., Mgr. Dept. of Safety and Relief, Illinois Steel Co., 208 S. LaSalle St., South Chicago, Ill. Res., 1538 E. Marquette Road. March 26, 1913.

MEMBERSHIP: FIRM MEMBERS

- 1 J. Sales Engr., Manning Maxwell & Moore, Park Bldg.
Pittsburgh, Pa. Res., 6366½ Forward Ave. May 1, 1915.
- 2 ER, R. V., E. E., H. Koppers Co., Pgh., Pa. Res., Sewickley.
Feb. 17, 1917.

FIRM MEMBERS

- ALAN WOOD IRON & STEEL Co., Richard G. Wood, Pres., 1801
Widener Bldg., Philadelphia, Pa. March 17, 1917.
- AMERICAN ROLLING MILL CO., THE, Geo. M. Verity, Pres., Middle-
town, Ohio. Jan. 20, 1917.
- AMERICAN SHEET & TIN PLATE CO., E. W. Pargny, Pres., 1322
Frick Bldg., Pittsburgh, Pa. Jan. 20, 1917.
- AMERICAN STEEL & WIRE CO., C. L. Miller, V. P. & Genl. Supt.,
828 Frick Bldg., Pittsburgh, Pa. Jan. 20, 1917.
- APOLLO STEEL CO., Robert Lock, Pres., Apollo, Pa. Jan. 20, 1917.
- BETHLEHEM STEEL CO., Eugene G. Grace, Pres., So. Bethlehem,
Pa. Jan. 20, 1917.
- BRIER HILL STEEL CO., TH. J. Thomas, President, Youngs-
town, O.
- CARNEGIE STEEL CO., Pres., Pittsburgh, Pa. Jan.
20, 1917.
- FORGED STEEL WHEEL CO., J. M. Hanson, Pres., 1120 Frick Bldg.,
Pittsburgh, Pa. March 17, 1917.
- ILLINOIS STEEL CO., E. J. Buffington, President, 208 So. LaSalle
St., Chicago, Ill. Jan. 20, 1917.
- INLAND STEEL CO., A. W. Thompson, Pres., 1st Natl. Bank Bldg.,
Chicago, Ill. Jan. 20, 1917.
- LA BELLE IRON WORKS, R. C. Kirk, Pres., Steubenville, O. Jan.
20, 1917.
- LACKAWANNA STEEL CO., E. A. S. Clarke, Pres., No. 2, Rector
St., New York, N. Y. Jan. 20, 1917.
- LORAIN STEEL CO., THE, Daniel Coolidge, Pres., Johnstown, Pa.
Jan. 20, 1917.
- MIDVALE STEEL CO., THE, A. C. Dinkey, Pres., Philadelphia, Pa.
Feb. 17, 1917.
- NATIONAL TUBE CO., Wm. B. Schiller, Pres., Frick Bldg., Pitts-
burgh, Pa. Jan. 20, 1917.
- PHILLIPS SHEET & TIN PLATE CO., E. T. Weir, Pres., Weirton,
W. Va. Jan. 20, 1917.
- PITTSBURGH STEEL CO., Wallace H. Rowe, Pres., Frick Bldg.,
Pittsburgh, Pa. Jan. 20, 1917.
- REPUBLIC IRON & STEEL CO., Thos. J. Bray, Pres., Youngstown,
O. Jan. 20, 1917.
- SHARON STEEL HOOP CO., Severn P. Ker, Pres., Sharon, Pa. Jan.
20, 1917.

STEEL COMPANY OF CANADA, LTD., THE, Robert Hobson, Pres.,
Hamilton, Ont. Jan. 20, 1917.

TENNESSEE COAL, IRON, & R. R. CO., Geo. Gordon Crawford,
Pres., Birmingham, Ala. Jan. 20, 1917.

WISCONSIN STEEL CO., H. F. Perkins, Pres., 606 S. Michigan
Boulevard, Chicago, Ill. Jan. 20, 1917.

YOUNGSTOWN SHEET & TUBE CO., Jas. A. Campbell, Pres.,
Youngstown, O. Jan. 20, 1917.

SUMMARY

Honorary Members	-	-	-	6
Active Members	-	-	-	171
Associate Members	-	-	-	349
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TOTAL	-	-	-	526
Firm Members	-	-	-	24

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Some Recent Advances in Industrial Lighting Equipment—
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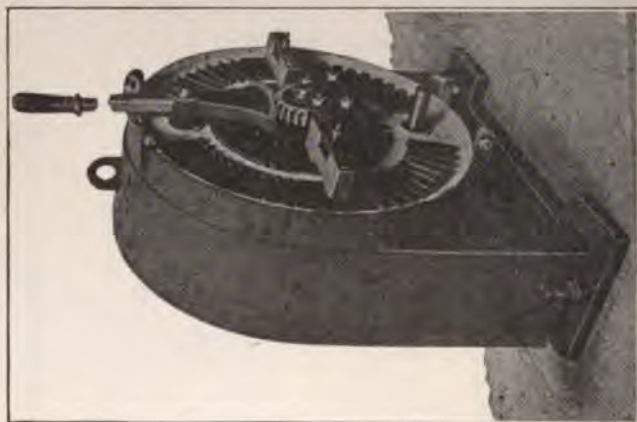
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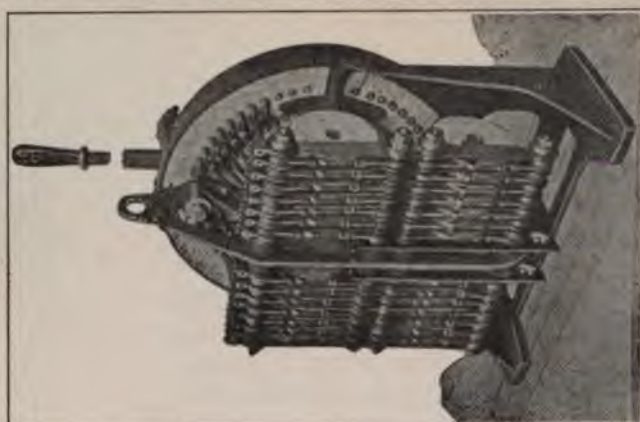
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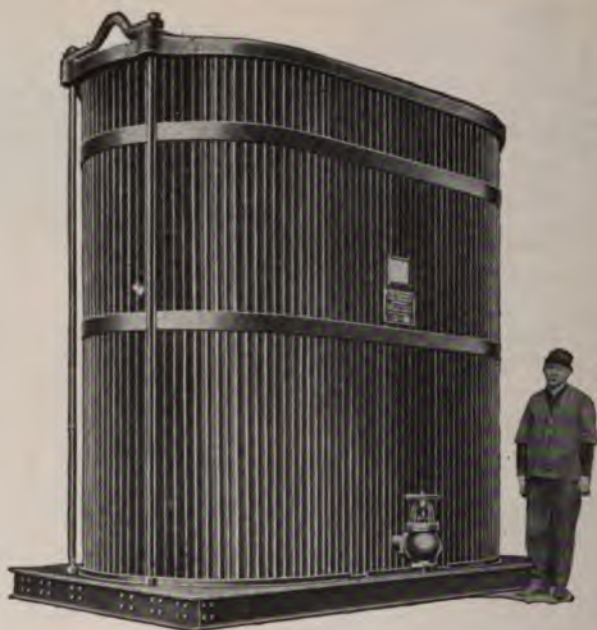
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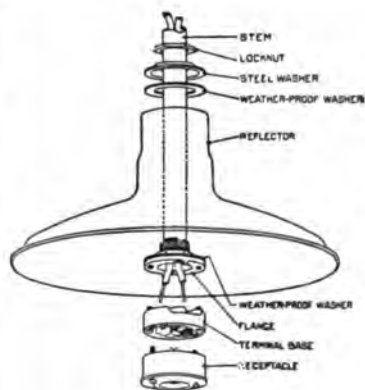
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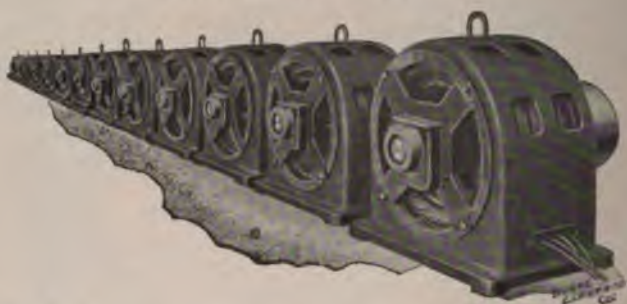
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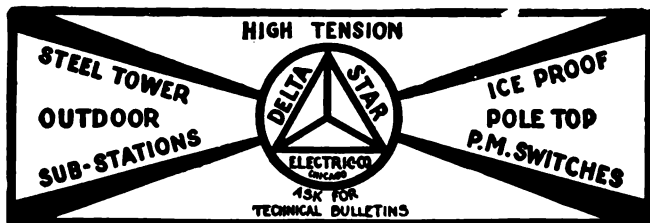
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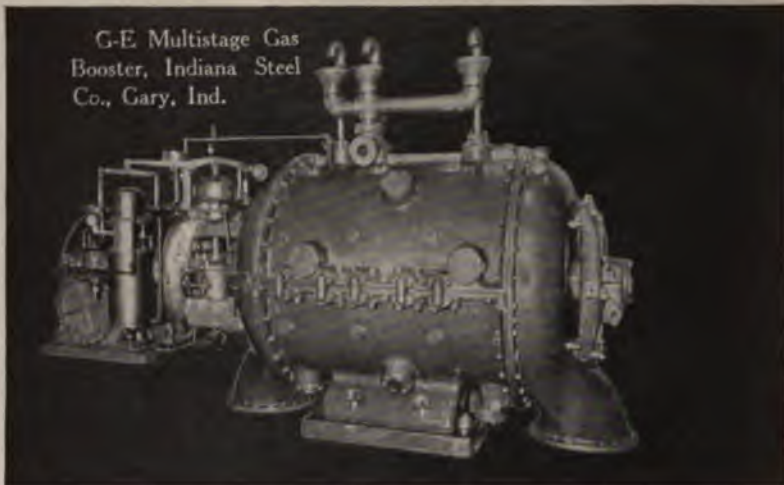
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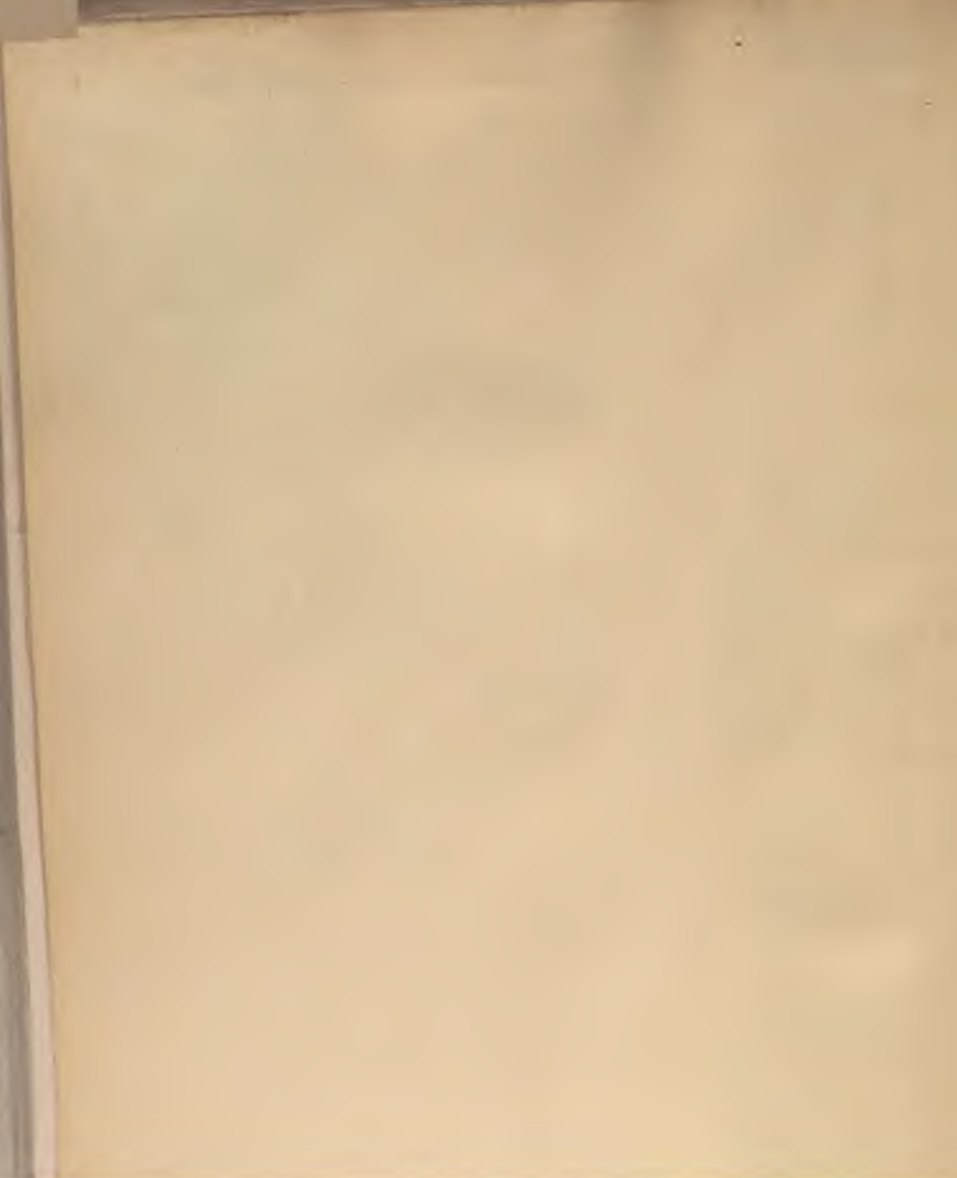
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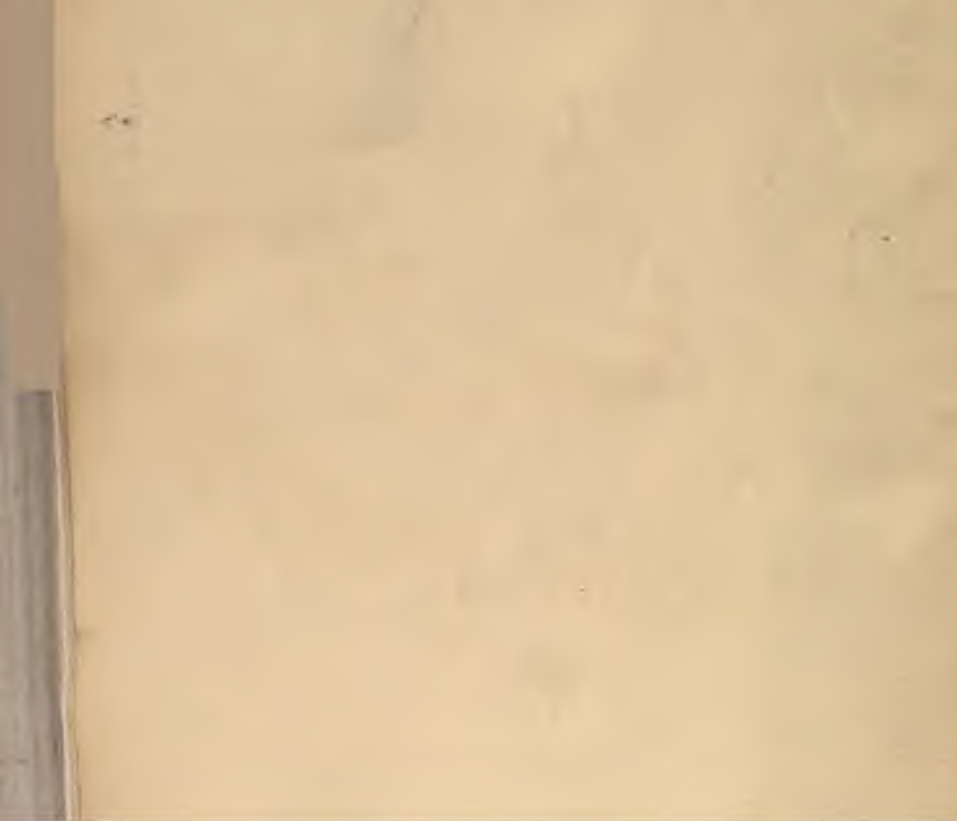
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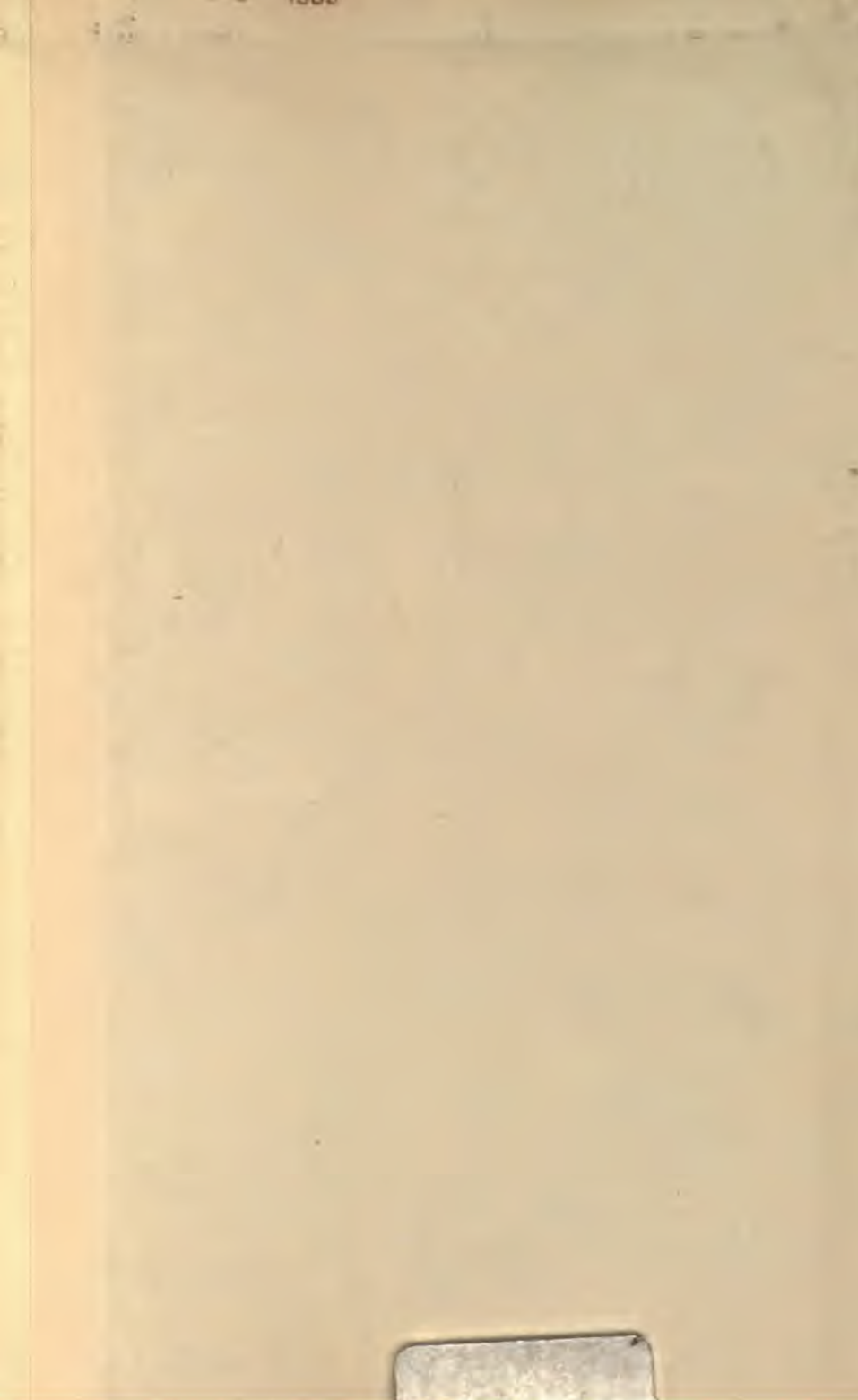
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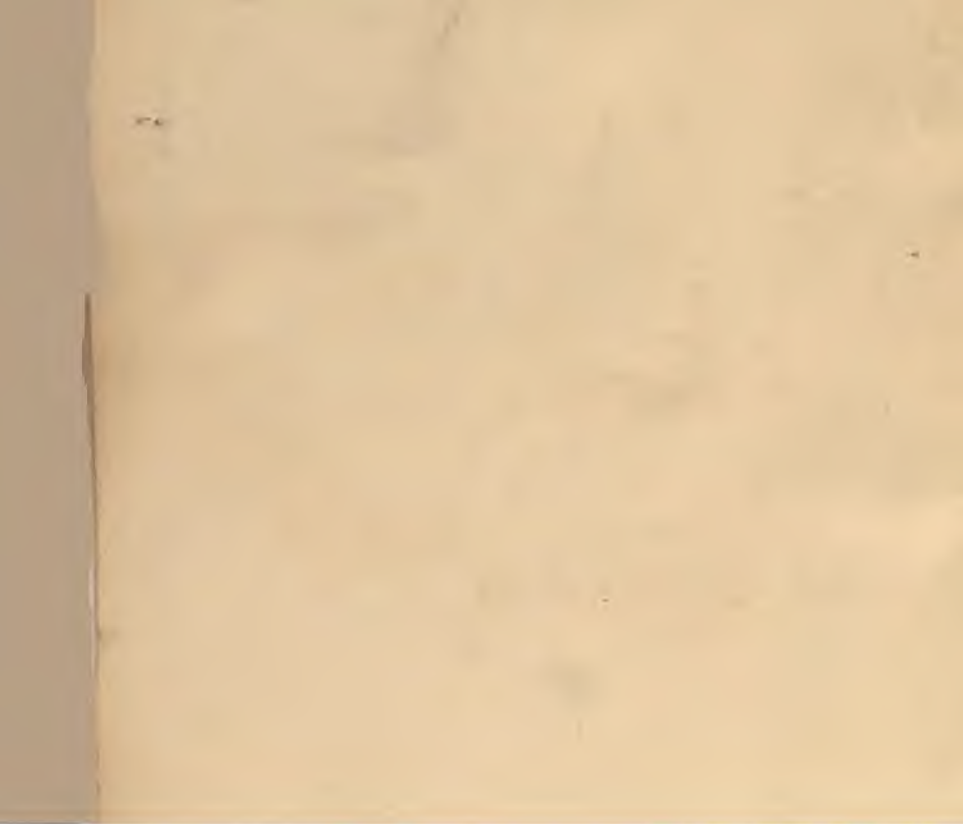
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